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Hypermarket competition and the diffusion of retail checkout barcode scanning

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Abstract

This paper presents a set of panel data to study the diffusion of retail checkout barcode scanning in ten European countries over the period 1981-1996. Estimates from a standard diffusion model suggest that countries differ most in the long-run diffusion level of barcode scanning and less in timing or diffusion speed. We present evidence that the emergence of hypermarkets raises competitive intensity and use hypermarket data, among other variables, in a pooled estimation. Results suggest that hypermarket competition reduces long-run adoption of information technology (IT) in retailing. In particular, the emergence of hypermarkets seems to deepen retail segmentation by inducing potential adopters (e.g. supermarkets) to exit the market and/or by discouraging adoption by other retail formats. Consistent with expectations, scale and income effects spur IT diffusion and there is a classic substitution effect: when wages rise, diffusion of a labor-saving technology such as barcode scanning is more intense. We do not find a significant impact of employment protection legislation.

JEL classification: L5, L81, O33.

Keywords: IT diffusion; retail competition; hypermarkets.

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1 Introduction

The retail sector has recently gained attention from two rather independent research streams: a literature devoted to productivity effects of information technology (IT) on the one hand, and a literature concerning the industrial organization and regulation of retail markets on the other hand. First, cross-country productivity studies attribute large post-1995 productivity gains in the United States to increased IT usage mainly in the distribution sector. Some even identify a 'retail revolution' (Ark et al., 2005; Nakamura, 1999). Most European countries, however, have not experienced such a manifest development in retail productivity (Timmer and Inklaar, 2005). Second, industrial organization scholars – alarmed by the growth of globally organised retailers such as *Wal-Mart*, *Carrefour* and *Tesco* – analyse the emergence of large-scale retailing, particularly in the form of hypermarkets, and the associated increase in market power (Dobson and Waterson, 1999; European Commission, 1999; FTC, 2001; Competition Commission, 2000).

A closer look reveals that both research streams are strongly related. Most prominently, insufficient productivity performances are often ascribed to anti-competitive retail regulation (McKinsey Global Institute, 2002; Scarpetta et al., 2002). Yet, despite a rich parallel literature on the link between retail regulation and employment (Bertrand and Kramarz, 2002, for example), empirical studies of the relationship between retail regulation or competition on the one hand and retail innovation or productivity on the other hand are rare. We are only aware of studies based on firm-level data, for example Foster et al. (2002) and Levin et al. (1992). Firm-level data, however, typically lack variation in the regulatory environment and hence provide little opportunity to examine important policy issues.

In this paper, we take a cross-country perspective to analyse the relationship between a distinct form of regulated retail competition (hypermarket competition) and diffusion of a distinct retail IT (barcode scanning). We abstract from productivity concerns: given that IT investments are productive, why is their intensity so different across industrialised countries? Using data on the diffusion of barcode scanning in retail outlets of ten European countries, we first obtain country-specific estimates for a standard diffusion model. Results indicate substantial cross-country differences in the long-run diffusion level of barcode scanning, corroborating the findings in the productivity literature. Then, we add data on a number of explanatory factors and assess their effect on IT diffusion in a pooled estimation.

Our particular focus is on the role of hypermarkets in retail competition and IT diffusion. While we present evidence that the emergence of hypermarkets represents an increase in the intensity of competition in retailing, results from the pooled estimation suggest that such competition has reduced the long-run IT diffusion level. We identify two – potentially independent – effects that may drive this result. First, hypermarket competition induces a *selection effect*: hypermarket entry seems to cause exit of potential IT adopters, namely smaller-sized supermarkets. Second, there is an *encouragement effect*: hypermarkets presumably adopt barcode scanning early and thereby dis- or encourage subsequent adoptions of rival retail formats.

We also consider other explanatory factors. In particular, we find evidence for a classic substitution effect: when wages rise, diffusion of a labor-saving technology such as barcode scanning is more intense. Scale and income effects are also important determinants of IT diffusion, results which may explain the U.S.-Europe divide in IT usage. We do not find a significant impact of employment protection legislation. While relevant in their own right, the above results may also help predict the upcoming "revolution at the checkout counter" (Brown, 1997), which will involve the replacement of barcode scanning by radio frequency identification (RFID).

The rest of the paper is organised as follows. In the following section, we present the data on checkout barcode scanning, our analytical approach to estimating a diffusion function, and results from country-wise estimations. In section 3, we introduce and discuss a number of determinants of IT diffusion and provide some precursory evidence on hypermarket competition. In section 4, we propose an econometric specification for pooled estimation and report respective results, including a number of robustness checks. Section 5 concludes the paper.

2 Checkout barcode scanning across Europe

We begin with a first glance at the data on barcode scanning in Europe. In contrast to the United States, where the first retail outlet was equipped with a barcode scanner already in 1974 (Nelson, 2001, and table 2), diffusion of barcode scanning in Europe did not take off before the 1980s. Until 1997, the national member organizations of the European Article Numbering Association (EAN) collected data on the number of retail outlets with scanner installations. These data are published for the years 1981 to 1996 in the yearly reports of the EAN. We combine this information with data on the total number of retail outlets in order to obtain a measure of the relative intensity of barcode scanning within a country.[1]

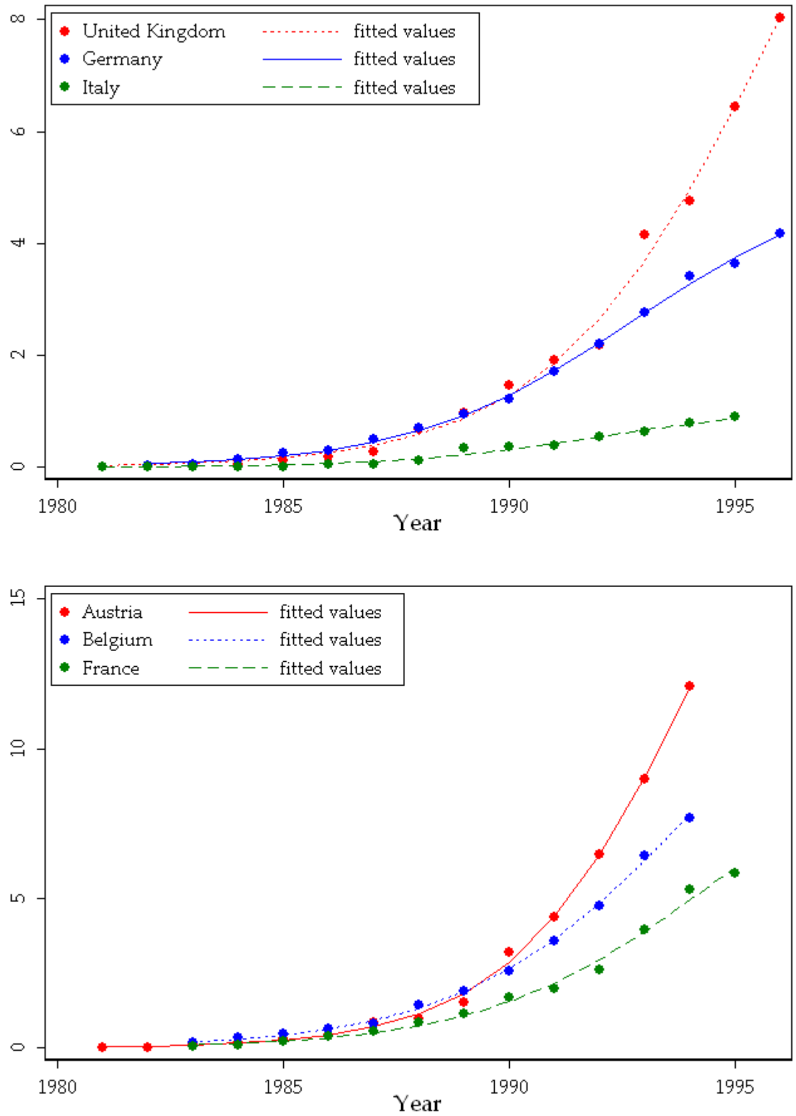
Accordingly, figure 1 indicates how many retail outlets use barcode scanning (in %, scatter points), separately for six of the ten countries we study. Figure 2 in the appendix plots the data for the remaining countries. Lines represent fitted values from a country-specific estimation of a logistic growth function (discussed below). While all series accord with a sigmoid-shaped curve common to diffusion processes, countries differ significantly in the intensity of barcode scanning. Our objective is to shed some light on the factors underlying these differences by means of a pooled estimation.

Yet, absolute cross-country differences should not be taken too literally. Countries may differ in measurement of the total number of retail outlets. For example, some countries may include mobile outlets ('street traders'), others not. In our pooled estimation described in section 4, we account for such potential differences. Nevertheless, country differences pertain if we relate the number of barcode scanning stores to population instead of outlet figures.

From today's perspective, these figures also appear to exhibit implausibly low adoption rates. After all, our daily grocery shopping experience suggests that barcode scanners are ubiquitous. Yet, notice that we consider not only grocery retailing, but the whole retail sector; which includes types of retailers who simply are not potential users of barcode

[1]The earliest EAN report available is the 1983 report, which also gives figures for 1981 and 1982 for most countries (or indicates that there were no scanning stores before 1983 in a particular country). The EAN reports include data for more than the ten countries we study. Our sample results from other data limitations. Section 3.1 presents the data and its sources in more detail.

Figure 1: Number of barcode scanning stores (in %, by country)



scanning – for example flower shops, repair shops or bakeries. Furthermore, the EAN data concern only fixed scanners in checkout counters. Many smaller retailers now work with hand-held or mobile barcode scanners. The way the EAN data is presented strongly suggests that it does not include such hand-held scanners: the 1994 report attempts to distinguish between fixed and hand-held scanners, but most countries (including those in our sample) only report the total number of scanning stores or relatively low figures for stores with hand-held scanners. Apparently, the EAN stopped data collection in 1997 not only because barcode scanning was considered a standard technology by then, but also because the increasing number of scanner types was hard to manage.[2] We argue below that – since it is restricted to checkout barcode scanning – for most countries in the sample our dataset is sufficient for an econometric study.

2.1 Analytical framework

In line with most empirical studies of aggregate data on diffusion, we employ the logistic function as analytical tool.[3] We use it in a reduced-form manner, although a number of theoretical models of new technology adoption generate diffusion patterns represented by the logistic or related functions (Geroski, 2000; Stoneman, 2002). The logistic function captures the typical sigmoid shape through three interpretable parameters:

$$\begin{aligned} S_t &= \frac{S^*}{1+\exp(-\beta(t-\tau))}, \\ \text{where} \quad S^* &= \gamma N_t. \end{aligned} \tag{1}$$

S_t indicates the number of adopters (outlets with a checkout barcode scanner) at time t. S^* is the potential number of adopters: the 'ceiling' or saturation level to which S_t converges. It is a fraction γ of the total number of outlets N_t.

Since the logistic function is symmetric, S_t equals half of its saturation level at the curve's inflection point: the date t at which the growth rate of the number of adopters is no longer increasing. τ indicates this inflection point and is hence a measure for the timing of adoption – it shifts the S-curve forwards or backwards on the timeline. Too see this, consider t^k, the moment in time where a share k of the saturation level is reached:

$$\begin{aligned} \frac{S^*}{1+\exp(-\beta(t^k-\tau))} &= kS^* \\ \text{or} \quad t^k &= \tau - \beta^{-1}\log(k^{-1}-1). \end{aligned}$$

At k =.5, $t^k = \tau$. Differentiating equation 1 with respect to time shows that coefficient β is a measure for the speed of adoption. It gives the growth rate of S_t, relative to its distance

[2]In a telephone conversation with German EAN representatives, we were told that collection of these data became increasingly difficult during the mid-1990s.

[3]With micro data, discrete choice and hazard rate models are commonly used, for example see Karshenas and Stoneman (1993), Åstebro (2004), and the references therein.

to the saturation level: $\frac{\mathrm{d}S_t}{\mathrm{d}t}\frac{1}{S_t} = \beta\frac{S^*-S_t}{S^*}$. The growth rate of S_t attains it's maximum, $\frac{\beta}{2}$, at the inflection point $t = \tau$.

Our approach differs from earlier diffusion studies in two respects. First, these studies often follow the seminal work by Griliches (1957) and use another version of equation 1, where $S_t = \frac{S^*}{1+\exp(-\alpha-\beta t)}$. Whereas the advantage of that approach is that it lends itself easily to log-linearisation, its disadvantage is that α is erroneously interpreted as a pure timing indicator. Instead, equation 1 shows that $\alpha = \beta\tau$ and hence 'timing' estimates for α resulting from the traditional approach are strongly correlated with respective 'speed' estimates for β. Second, most other studies relate the speed or timing coefficients of equation 1 to independent variables (Gruber and Verboven, 2001, for example), whereas we focus on the saturation level γ in our pooled estimation (section 4). Actually, in a late comment on his earlier work, Zvi Griliches proposed to do exactly that:

> "Adding parameters to the curve itself or fiddling with the functional form is not an attractive alternative, in my opinion. What one gains in fit one loses in interpretability. Instead, I would now respecify the model so that the ceiling is itself a function of economic variables that change over time."
> (Griliches, 1980, p. 1463)

2.2 Country-wise estimation

We obtain the fitted values shown in figure 1 from country-specific nonlinear least squares (NLS) estimations of equation 1 with an additive i.i.d. error term. N_t – the number of outlets – is counted in hundreds such that γ indicates the saturation level as the percentage of barcode scanning stores. Table 1 provides more detailed results on these estimations. In line with the productivity studies cited before, cross-country differences seem to be most pronounced with respect to the saturation level of IT adoption as measured by $\hat{\gamma}_i$.

For example, Austria is estimated to have about 24% of outlets with barcode scanning in the long run but Italy only 1%. Again, these differences arise not only from different adoption patterns (S_t) but also from different underlying retail market structures (N_t). The Italian retail market, for example, is still highly segmented, with many small but specialized retailers selling goods that in other countries are sold jointly by larger retail-

Table 1: Estimates from country-wise regressions*

Country	$\hat{\gamma}_i$	$\hat{\beta}_i$	$\hat{\tau}_i$	Observations	R^2
Austria	24.2[a]	.50[a]	1994.0	14	.999
Belgium	16.0[a]	.39	1994.1	12	.999
Denmark	10.7	.42	1992.1	15	.992
France	10.7	.41	1994.4	13	.996
Germany	5.2[a]	.41	1992.7[a]	15	.999
Ireland	1.3[a]	.48	1992.7[a]	16	.998
Italy	1.1[a]	.45	1992.0	15	.986
Netherlands	7.6	.31[a]	1994.8	14	.997
Spain	3.9[a]	.39	1995.1	16	.978
United Kingdom	15.4	.41	1995.8	16	.995
Cross-country average	9.6	.42	1993.8	10	

*Parameter estimates from country-wise NLS estimation of equation 1.
[a]Coefficient differs significantly from cross-country average
(95% confidence level, F-test based on asymptotic standard errors).

ers. Cross-country differences with respect to timing and speed of diffusion seem less pronounced. Only in two cases do estimates for β_i and τ_i differ significantly from the cross-country average (which implies 20% growth in the number of barcode scanning stores around year 1994). We therefore focus on explaining differences in γ_i with a joint regression analysis of the panel.

The estimated saturation level for Ireland also deserves a note. In contrast to the Italian case, we are rather surprised by the low value, since Ireland's retail structure is more comparable to the UK's (cf. table 7 in the appendix). As Ireland has developed strongly throughout the 1990s, we presume that our data cover only the very beginning of a corresponding diffusion process. In other words, our series for Ireland may lack its inflection point, which would lead to unreliable estimates (Debecker and Modis, 1994). We get back to this point in section 4.

Regarding all other countries in our sample, a comparison of these estimates to U.S. figures suggests that our data should cover a sufficient part of the diffusion process. U.S. trade magazines stopped reporting detailed adoption figures already in 1985. Table 2, which compiles U.S. data from various sources, shows that the number of barcode scanning stores started to rise slowly in the mid-1970s and quickly went up in the late 1970s and early 1980s.[4] But at least within the group of food retailers – the main users of fixed checkout scanners – U.S. growth appears to have come to a halt by the end of the 1980s. With Europe's time lag being roughly a decade, we should expect diffusion of fixed scanner installations in Europe to slow down by the end of the 1990s, with the series' inflection points in the early 1990s, as reflected by the τ-estimates in the above table.

Table 2: Percentage of barcode scanning stores: U.S. data, 1974-1984*

Year	Scanning stores[a] (number)	Outlets with payroll[b]	Scanning stores (%)	Scanning food stores (%)[c]
1974	6	726940	<.00001	
1976	97	744780	<.00001	
1980	2483	738100	.00003	
1982	5902	784700	.00008	
1984	9278	831300	.00011	
1988				59.7
1989				57.7

*Sources: [a]Euromonitor (1986), which cites trade publication *Chain Store Age*. [b]U.S. Bureau of the Census (1978, and later issues). [c]Food Marketing Institute (1989,1990), based on a survey of approx. 10,000 food retailers.

2.3 Functional form and autocorrelation

The logistic is probably the simplest functional form available to study sigmoid-shaped diffusion patterns, however, it may not be the most appropriate. In particular, erroneously assumed symmetry around the inflection point may bias estimates. We therefore re-estimated country-specific saturation levels using the Gompertz function, which is similar to the logistic but asymmetric around the inflection point (Franses, 2002, for example). For five countries, these estimates and the respective fit statistics do not differ much from those based on the logistic function. For the other five countries, however, the estimated inflection point lies beyond the year 2003, fit statistics are poorer than or comparable to those for the logistic function, and the estimated saturation level is very large – in three cases even larger than 100% (results available upon request). We conclude that the logistic function is the more appropriate functional form for our data.

[4]Das and Mulligan (2004) argue that frequent vintage changes of fixed scanners between 1975 and 1985 affect U.S. diffusion estimates. As post-1980 vintages were sold for relatively long time periods, we do not consider this a significant problem for our dataset.

Another issue in estimating growth curves is potential autocorrelation. Following the procedure proposed by Franses (2002), in unreported test regressions we reject the null hypothesis of no autocorrelation against the alternative of AR(1) errors only for two countries. Yet, re-estimating a logistic function with an AR(1) error term for these countries leads to autocorrelation coefficients which are not significantly different from zero. We therefore retain the assumption of an AR(0) error term throughout the rest of the paper.

3 Explaining country differences

In this section, we present our set of independent variables and relate them to theoretical explanations for differences in the diffusion of barcode scanning. In particular, we assess technology-specific factors (section 3.2), employment protection legislation (section 3.3), as well as hypermarket competition and product market regulation (section 3.4). Related literature is discussed along the way. We also present and discuss some precursory evidence. In section 4, we present our econometric specification for the pooled estimation and the corresponding results.

3.1 Retail sector data

Publicly available information on the retail sector is scarce, even on a country-year basis. Although we compile data from various sources, various limitations make us restrict attention to the 10 countries listed in table 1. Table 3 gives a description of the main independent variables used in section 4. For more detailed cross-country summary statistics, see table 7 in the appendix. Source of *GDP* and population figures is the World Bank (2003). Data on the number of hypermarkets and the total number of retail outlets are from various issues of "Retail trade international", a publication by market research firm Euromonitor. The most recent issue is Euromonitor (2002).

As a measure for the severity of labor market restrictions, we use version 1 of the revised OECD indicator of the strictness of employment protection legislation (OECD, 2004). The indicator of retail sales volume (*VOL*) is also from the OECD.[5] The retail *WAGE* index

[5]For Italy and Spain, this indicator does not cover the whole sample period. For these two countries, we therefore constructed a comparable indicator based on Euromonitor and GGDC data (see appendix).

is constructed using data from the 60-Industry Database of the Groningen Growth and Development Centre (GGDC). Pre-1990 values for unified Germany for the variables *VOL* and *WAGE* were constructed by applying pre-1990 trends for Western Germany to 1990 values for unified Germany. We also had to replace some missing values with univariate procedures. Appendix A provides a detailed list of all data manipulations.

Table 3: Summary of independent variables

Label	Description	Source	Cross-country mean 1981 / 1996
OUT	No. of retail outlets (per mn. inhabitants)	Euromonitor, World Bank	9361.8 / 7952.4
HYP	No. of hypermarkets (per mn. inhabitants)	Euromonitor, World Bank	6.8 / 13.3
EPL	OECD indicator of strictness of employment protection legislation	OECD	2.5 / 2.2
WAGE	Retail hourly real wage (index 1995=100)	GGDC, World Bank	74.2 / 101.1
GDP	Per capita real GDP (index 1995=100)	World Bank	74.8 / 102.1
VOL	Retail sales volume (index 1995=100)	OECD, Euromonitor	85.7 / 101.3

We were unable to obtain information on a number of factors that may also be important in our analysis, such as prices for scanning equipment, opening hours, the importance of multinational firms, or average store size. As long as these omitted factors are relatively time-invariant or equal for the countries in our sample, our results should not be affected significantly. Let us now turn to the theoretical predictions regarding the effects of the included factors on the diffusion of checkout barcode scanning.

3.2 Technology-specific effects

When deciding about the adoption of a new technology, a firm typically compares costs and benefits of adoption at a given point in time (Hall and Khan, 2003). For example, heterogeneity across potential adopters regarding these costs or benefits may be one reason why diffusion of new technology is rarely instantaneous. In our case, the installation of a barcode scanner represents a major capital investment that basically enables a retailer to check out more retail items in less labor time.[6] Following the discussion by Levin et al. (1987, 1992), a number of factors can make barcode scanning more or less valuable in different countries.[7]

First, the financial returns to such a capital investment depend on future market conditions. Since return-on-investment is quicker in growing markets, retailers there will adopt more intensely than retailers in stagnating or contracting markets. In addition, barcode scanning may introduce or increase economies of scale in retailing. In both cases, we expect adoption intensity to increase with market volume (*VOL*). Second, barcode scanning is likely to reduce customer waiting time at the checkout. Customers in high-income countries have a higher opportunity cost of waiting. Using per capita *GDP* as income measure, we expect diffusion of barcode scanning to increase with *GDP*. Notice that in this interpretation, barcode scanning is a product-enhancing innovation: it increases the quality of retailing for the costumer.

Another, rather classical interpretation regards barcode scanning as a process-enhancing innovation that reduces the costs of retailing. Most prominently, barcode scanning may be a labor-saving technology that reduces total labor demand. In addition to this classic capital-labor substitution effect, barcode scanning may allow retailers to substitute unskilled for costly skilled labor. Clerks at scanner checkouts need neither know prices nor be able to type quickly. In both cases of substitution, we therefore expect countries with rising retail wages – as measured by variable *WAGE* – to invest more in a labor-saving technology such as barcode scanning.

3.3 Employment protection legislation

A related question is whether labor market restraints hinder IT diffusion. For example, strict employment protection legislation (EPL) may prohibit retailers from substituting barcode scanners for labor as extensively as the technology might allow. Accordingly, a conventional wisdom has been that less flexible labor markets (with stricter EPL) im-

[6] Clearly, barcode scanning also facilitates other potentially productivity-enhancing practices, e.g. sophisticated logistics systems ('efficient consumer response', 'category management'); but these systems did not develop before the mid-1990s and still represent "untapped potential" (Haberman, 2001).

[7] Levin et al. (1987, 1992) study the adoption of barcode scanning in U.S. retailing. They analyse firm-specific data relating to the early years of the technology (1974-1985).

pede IT adoption (IMF, 2001, for example); with corresponding policy recommendations. Yet, the literature on the relationship between labor market regulation such as EPL and innovation provides mixed results (Bassanini and Ernst, 2002, for a review).

In support of the conventional view, Gust and Marquez (2004) analyse a panel of cross-country data and find that IT investments are lower in countries with higher EPL. In contrast, Koeniger (2005) finds a positive effect of EPL on innovative activity – at least in the short- and medium-term – for a panel of OECD countries. He also shows theoretically, that EPL in the form of collective dismissal costs may increase innovative activities. Accordingly, Agell (1999) argues that labor market regulations, in particular EPL, need not reduce investment incentives and productive efficiency, as they provide insurance against adverse economic shocks or structural shifts in labor demand. Haucap and Wey (2004) show that labor market rigidities can increase firms investment incentives when they tend to enforce egalitarian wage structures.

3.4 Product market regulation and hypermarket competition

In the industrial organization literature, retail markets have typically been regarded as more or less perfectly competitive. This perception has led scholars to abstract from the retail level and concentrate on the manufacturers' side. Yet, fragmented retail structures are most often the direct result of entry restrictions. In general, these restrictions tend to favor small retailing in downtown areas against large scale retail formats as exemplified by *Wal-Mart*. Most prominently, planning and construction restrictions have been used in all European countries to ban large retailing formation; e.g., by not granting construction permissions or by limiting store size. See Faini et al. (2004) for a recent account of retail restrictions in the UK, Italy and Germany. Bertrand and Kramarz (2002) provide empirical evidence for France. These restrictions have been eased first in the U.K. by the Thatcher government and later in other European countries as well.[8]

With these developments, hypermarkets have become an integral element of European retail markets. According to a widely used definition, hypermarkets have a minimum size of 2,500 square meters, and sell both food and non-food items. Hypermarkets often

[8]In 1996, hence at the very end of our sample period, U.K. retail regulation turned towards a more restrictive approach favoring city centres (Haskel and Sadun, 2005).

locate in peripheral areas which are easily accessible by car. In most European countries, the hypermarket retail format emerged in the 1970s and 1980s, parallel to an increase in motorization.[9]

We claim that the number of hypermarkets per capita (*HYP*) is an inverse indicator of entry restrictions. An increasing number of hypermarkets is a result from less restrictive entry regulations, and hence a proxy for increasing competitive intensity due to regulatory change. Moreover, hypermarkets may reflect competitive intensity on other grounds. They can be regarded as low-cost competitors who exploit the cost benefits of out-of-town locations, sophisticated logistics, and economies of scale (Basker, 2004). One may also view retail competition as competition of retail channels or formats (Michael, 1994; Smith and Hay, 2005). In that sense, the emergence and growth of a new format, like the hypermarket, intensifies retail competition as such.

Table 4 presents some evidence in support of our claim. Since retail competition essentially works through entry and exit of firms (Foster et al., 2002), the appearance of competitive hypermarkets should have led to increased exit rates. We therefore regress the number of non-hypermarket outlets on the number of hypermarkets: (*OUT - HYP*) on *HYP* (all in per capita terms). Two countries in our sample – Germany and Denmark – apply a slightly broader hypermarket definition which includes superstores (supermarkets with a floor space between 1,500 and 2,500 square meters). Accordingly, we allow for a different effect for these two countries, the difference measured by the coefficient for *D*HYP*.

As expected, an increase in the number of hypermarkets is estimated to lead to a decrease in the number of other retail outlets. The first column of table 4 provides results under the assumption that there are country fixed effects but no time trends in the number of outlets time series. The coefficient for the standard hypermarket definition (*HYP*) implies that an additional hypermarket outlet per million inhabitants is estimated to induce almost 197 other retail outlets per million inhabitants to exit the market. Yet, the estimated coefficient for the broader definition employed by Germany and Denmark is significantly positive (-196.9+298.3). We interpret this result as an indication that Ger-

[9]The French retail group *Carrefour* claims to have invented the concept. It opened its first hypermarket in 1963 near Paris, "with a floor space of 2,500 square meters, 12 checkouts and 400 parking spaces" (see `www.carrefour.com/english/groupecarrefour/annees60.jsp`).

Table 4: Regression results on hypermarket competition*

	Dependent variable:			
	(*OUT - HYP*)	(*OUT - HYP*)	(*OUT - HYP*)	(*OUT - SUPHYP*)
Independent variable	Coefficient	Coefficient	Coefficient	Coefficient
HYP	-196.921[a]	-196.921[a]	-31.204	
	(25.898)	(26.881)	(48.340)	
*D*HYP*	298.300[a]	103.574	-68.124	
	(60.212)	(122.356)	(121.573)	
SUPHYP				-.972
				(1.052)
Country excluded:		Germany		Germany
Country fixed effects:	yes	yes	yes	yes
Country time trend:	no	no	yes	yes
Time span (max.)	1980-2001	1980-2001	1980-2001	1980-2001
Observations	215	193	215	182
R^2	.959	.958	.991	.991

*OLS estimates (country fixed effects and time trends omitted). Standard errors in parentheses ([a] indicates significance with 95% confidence). *D* is a dummy variable equal to one for Germany and Denmark, who use a different hypermarket definition than the other countries. *SUPHYP* is the number of super- and hypermarkets per mn. inhabitants (Source: Euromonitor; 12 obs. missing, see data appendix).

many's series for outlets and hypermarkets are somewhat special. They seem heavily affected by two rather independent post-1990 developments following re-unification: (*i*) an overall catch-up in the number of outlets in former East Germany and (*ii*) the construction of large retail sites – namely superstores and hypermarkets – outside of former East German cities. Indeed, when we exclude Germany from the sample (second column), the estimated difference between the Danish-German and the standard hypermarket definition (*D*HYP*) is no longer significantly different from zero, suggesting that the overall hypermarket effect is negative for Denmark as well. The estimate for all other countries (*HYP*) by definition remains unchanged.

The inclusion of country-specific time trends somewhat improves fit, as measured by R^2 (third column). The average hypermarket effect is then smaller, but negative for both hypermarket definitions. An additional hypermarket per million inhabitants (*HYP*) is estimated to induce exit of 31 other retailers (99 for Denmark), although the effect is not significant. Also, the Denmark-specific insignificance in column two suggests that hypermarkets indeed imply more competitive threat than smaller modern retail formats like superstores or supermarkets, which are partially included in Denmark's hypermarket figures. In order to assess this hypothesis in more detail, we looked at results with the joint number of hyper- and supermarkets (*SUPHYP*) as an alternative regressor (fourth column).[10] The estimated average effect of *SUPHYP* on the number of other outlets is close to zero. We conclude that the number of hypermarkets is a valid proxy for the intensity of retail competition and a better indicator than the number of superstores or supermarkets.[11]

Having established that emerging hypermarkets represent more intense competition, what should we expect regarding their effect on the diffusion of barcode scanning? We are not aware of theoretical or empirical work that relates particularly to retail deregulation or hypermarket retailing and IT diffusion. But the relationship between competition and technology diffusion has been studied on a more general level (for a review see, in particular, Stoneman, 2002). Götz (1999) studies the diffusion of new technology in a monopolistically competitive industry. He finds that increased competition often promotes diffusion. In contrast, Boucekkine et al. (2004) study a differentiated-products Cournot duopoly and find an inversely U-shaped relationship between competition and diffusion. In their model, an increase in competition (a decrease in product differentiation) stimulates diffusion only when products are sufficiently substitutable.

The closely related literature on the relationship between market structure and innovation incentives has also delivered contradictory results. While the Schumpeterian (1942) idea has been that there is a positive relationship between innovation incentives and concentration or large firms, others have emphasised the negative effects of monopoly power on innovation. Borrowing from the parallel literature on market structure and product quality, one may also claim that the influence of market structure on innovation is neutral, or in general ambiguous (Swan, 1970; Spence, 1975).

Empirical results mirror this theoretical ambiguity (Geroski, 2000; Karshenas and Stoneman, 1995, for reviews). For example, Levin et al. (1987, 1992) find that retailers adopt earlier and that intra-firm diffusion of barcode scanning is faster in markets that are less concentrated, but these effects partially bare significance. More importantly, as we ar-

[10] In this case, we do not have to distinguish between definitions, since it does not matter how stores at the margin between super- and hypermarkets are classified.

[11] Due to a number of problems associated with the supermarket data (see appendix), we regard these supermarket-specific results as complementary, but refrain from using respective data in more detail.

gued above, concentration measures are not necessarily good proxies for competitive intensity in retail markets.

In our particular case, hypermarket competition may have two – potentially independent – effects on IT adoption by other retailers. On the one hand, we find that hypermarket entry induces exit of other retailers. If the exiting retailers predominantly belong to the group of (potential) IT adopters, this *selection effect* reduces the share of adopters in the group of remaining retailers. On the other hand, hypermarket competition can have an *encouragement effect* on the group of remaining retailers, for example when hypermarket entry leads former non-adopters to become (potential) adopters. With aggregate data on IT diffusion, we can only identify the joint impact of these two effects, which can be positive or negative.

Consider a simple numerical example as illustration. Imagine a country with 100 retailers, 50 of which are potential adopters of barcode scanning. There are no hypermarkets yet. While barcode scanning diffuses, one of the retailers decides to transform into a hypermarket, which drives 10 other retailers out of business. Depending on whether these 10 quitting retailers were potential adopters or not, the *selection effect* of the hypermarket on long-run diffusion of barcode scanning can be negative or positive. In case all quitters were non-adopters, the long-run diffusion level of barcode scanning increases from .5 to .56 (50 out of 90). In case they had been (potential) adopters, it reduces from .5 to .44 (40 out of 90). Moreover, an *encouragement effect* of increased competition could be that some of the previous non-adopters become potential adopters of barcode scanning, which raises its long-run diffusion level.

3.5 Bivariate correlations

For a first idea on how the discussed factors might relate to cross-country differences in barcode scanning, a useful approach is the one pioneered by Zvi Griliches (1957). He relates group-specific parameter estimates to independent statistics. In this vein, we assess how the countries' separately estimated saturation levels correlate with trends of the proposed variables in the respective time period. Table 5 lists the correlation coefficients.

Table 5: Bivariate correlations between $\hat{\gamma}_i$ and independent variables*

Correlation between					
			trend coefficient for		
	log(*HYP*)	log(*EPL*)	log(*WAGE*)	log(*GDP*)	log(*VOL*)
and $\hat{\gamma}_i$	-.526	.512	.501	.015	.581

*Based on nine observations (one per country, excluding Ireland): $\hat{\gamma}_i$ and trend coefficient from country-wise regression of log(independent variable) on time. Trend coefficients are significant with 95% confidence for all countries and variables except for two countries with variable *VOL*.

All bivariate correlation coefficients are in line with the above theoretical discussions. Estimated saturation levels are higher in countries with larger growth of GDP, retail sales volume, retail wages and employment protection, and lower in countries with larger hypermarket growth.[12] A negative hypermarket effect is surprisingly clear in the data: between 1981 and 1996, 5 out of 10 countries have an average yearly growth in the per-capita number of hypermarkets below 3% – as proxied by a trend coefficient in a regression of log(*HYP*). Average estimated saturation level is 12.7% for these countries (Austria, Belgium, Denmark, Germany, Netherlands), but only 6.5% for the other five countries that had stronger hypermarket growth. Yet, these bivariate correlations neither account for country-specific fixed effects in γ_i, which may arise solely from differences in counting retail outlets, nor for year-to-year and multivariate correlations.

4 Pooled estimation

In order to assess the effects of the proposed variables and at the same time account for time-invariant country-specific effects on the saturation level, we pool countries to estimate a joint diffusion function, in which we parameterise γ as follows:

$$\gamma = \gamma_i + X_{it}\gamma^x, \tag{2}$$

[12]When we include Ireland in calculating these correlation coefficients, only the coefficient for GDP changes qualitatively, resulting from Ireland's combination of strong GDP growth with a low γ-estimate.

where X_{it} contains the variables *HYP*, *EPL*, *VOL*, *GDP*, *WAGE* and *D*HYP*. As before *D* is a dummy variable equal to one for Germany and Denmark to account for the different hypermarket definition, and the number of outlets (N_t) is given in hundreds. Subscript $i = 1, ..., 10$ indicates countries and $t = 1981, ..., 1996$ indicates periods.

The coefficients γ_i account for time-invariant country-specific effects, as well as for time-invariant cross-country differences in measurement of the independent variables. Hence, γ^x estimates the average marginal effect of variable x on the country-specific saturation level. The speed and timing coefficients of equation 1 are allowed to vary across countries, hence we specify $\beta = \beta_i$ and $\tau = \tau_i$. In other words, we retain the full flexibility of the country-wise regressions and use the specification of equation 2 to ask whether the independent variables contain additional information regarding the diffusion of barcode scanning. After inserting equation 2 and an additive i.i.d. error term, we estimate equation 1 by NLS.[13]

Unreported regressions based on the full sample exhibited convergence problems and led to large and unstable estimates for Ireland's country-specific estimates (γ_i,β_i,τ_i). We actually find this result reaffirming in two respects. First, this seems to confirm the suspicion that the data for Ireland do not cover a sufficiently large portion of its diffusion of barcode scanning. Second, it suggests that the independent variables do contain additional information, since Ireland-specific estimates without these variables spuriously appeared stable. In what follows, we therefore present estimation results excluding Ireland. The independent variables' coefficients are virtually unaffected, compared to estimates including Ireland, but convergence is smoother and all country-specific estimates are now stable.

4.1 Results

The first column of Table 6 presents the results for our baseline specification (I). In addition, we present results for three alternative specifications: in specifications II, III and IV we exclude Germany; in specification III, we also exclude the variables *EPL* and *D*HYP*;

[13] We use the estimates from the country-wise regressions as initial values for country-specific effects. For the independent variables' coefficients, we set initial values equal to 0.

in specification IV, we exclude *D*HYP* and add an interaction term for the variables *EPL* and *HYP*.

Table 6: NLS estimation results*

Dependent variable: Number of barcode scanning stores				
Specification	(I)	(II)	(III)	(IV)
HYP	-1.852[a]	-1.744[a]	-1.756[a]	-2.153[a]
	(.426)	(.408)	(.425)	(.596)
*D*HYP*	6.668[a]	1.837		
	(2.505)	(2.154)		
EPL	-1.333	-1.154		-1.807
	(2.287)	(2.108)		(2.311)
*HYP*EPL*				.203
				(.179)
WAGE	.119[a]	.123[a]	.116[a]	.126[a]
	(.032)	(.031)	(.028)	(.033)
GDP	.394[a]	.385[a]	.408[a]	.368[a]
	(.069)	(.069)	(.061)	(.070)
VOL	.087[b]	.072	.062	.101[a]
	(.048)	(.047)	(.047)	(.048)
Country excluded:	Ireland	Ireland Germany	Ireland Germany	Ireland Germany
Time span (max.)	1981-1996	1981-1996	1981-1996	1981-1996
Observations	130	115	115	115
Adj. R^2	.994	.994	.994	.994
Root MSE	494.6	504.2	499.4	499.8

*Estimates for γ_i, β_i and τ_i omitted. Asymptotic standard errors in parentheses. Significance levels: [a] 95%, [b] 90%

The effects for variables *WAGE*, *GDP* and *VOL* vary little across specifications and are for the most part significantly estimated. A 10-point increase in the retail wage index is estimated to raise the saturation percentage of barcode scanning stores by about 1.2 points on average. A 10-point increase in real GDP per capita and retail sales volume raises the saturation percentage by about 4 and 1 points, respectively. All three results confirm initial expectations. First, investment in labor-saving retail IT can be interpreted as a reaction to changes in labor costs. Second, income, scale and returns-to-investment effects are important. Although the income effect measured by *GDP* seems more important than the scale effect measured by *VOL*, both effects are hard to distinguish empirically since the two variables are highly correlated by definition. Nevertheless, these estimated effects already can explain why the U.S. is ahead of most European countries when it comes to

IT diffusion in the retail sector and the resulting productivity gains throughout the 1990s: strong overall economic growth driven by a surge in consumer spending.[14]

Consistent with the bivariate correlation found before, an increase in the number of hypermarkets by one per million inhabitants is estimated to decrease the saturation percentage of barcode scanning stores by about 2 points. In aggregate terms, hypermarket competition therefore seems to reduce long-run IT usage in the retail sector. The question whether this hypermarket effect works by discouraging existing retailers from adoption (*encouragement effect*) or rather by driving potential adopters out of the market (*selection effect*) is one we cannot address with the data at hand. We suspect that both effects are at play. The impact of the selection effect may be more important, however, since hypermarkets mainly compete with supermarkets – the main group of potential adopters – and less with other, smaller retailers.

Yet, the negative result seems to hold only for the standard hypermarket definition. In our baseline specification I, the estimate for the Danish/German definition is positive (-1.9+6.7). As with our precursory results on hypermarket competition, this effect presumably arises from German re-unification efforts, where a large number of newly built retail outlets in East Germany have been equipped with barcode scanners from the start. We therefore re-estimated the model excluding Germany and find that Germany indeed seems to be a special case. The estimated difference between the broad hypermarket definition and the standard one, now a Denmark-specific effect, is much lower and not significantly different from zero. Accordingly, an estimation which ignores different hypermarket definitions by excluding the interaction term *D*HYP* (specification III) leads to an essentially unchanged hypermarket effect, as long as Germany remains excluded. In specification III we also exclude the *EPL* indicator, whose effect has the commonly expected negative sign but is insignificant in all estimations. Other estimates remain largely the same.

[14]Comparable OECD data for the retail volume indicator *VOL* indicate that, between 1990 and 2000, U.S. retail volume increased by about 67%, whereas it increased by about 30% in the U.K. and by about 7% in France. In Germany, retail volume decreased by about 1% between 1990 and 2000.

4.2 Robustness

All findings remain qualitatively unchanged in a number of robustness checks. First, complementarities between labor and product market conditions may affect our results. We therefore looked at results including an interaction term *HYP*EPL* (specification IV in table 6) or *EPL*WAGE* (results omitted). In both cases, the interaction term coefficients are rather close to and not significantly different from zero, while some other estimates slightly change in magnitude and precision but are otherwise unaffected.

A potential source of endogeneity bias is the presumption that every new hypermarket built from the mid-1980s increases the number of scanning outlets by one. Although not necessarily, since hypermarkets operated long before the introduction of barcode scanning and hence the technology may not be as crucial for them as it might appear from today's perspective. In any case, the negative estimates in table 6 already suggest that this endogeneity bias cannot be very influential. By deducting the number of hypermarkets from both the number of barcode scanning stores and the number of outlets, it is nevertheless possible to focus on the effect of hypermarket competition on the adoption of barcode scanning by all other retailers. The corresponding unreported results for specifications I to IV are virtually identical to those in table 6.

One may also suspect that there are effects driving reverse causality, namely that barcode scanning leads to an increase in average store size and eventually to more "superstores" or hypermarkets (Holmes, 2001). Yet, the facts that (*i*) hypermarkets existed long before barcode scanning was introduced and (*ii*) Holmes (2001) model predicts a positive correlation while we find a negative one lead us to believe that reverse causality is not a severe issue in our case.

Another potential source of error are the implicit assumptions in our method to construct time series for the total number of retail outlets (see data appendix). We therefore estimated specifications I to IV with a country's population (in millions) replacing the number of outlets in equation 1. Table 8 in the appendix presents the corresponding results. For specifications II to IV, all variables yield estimates with the same qualitative effects on the long-run number of barcode scanning stores per capita; except EPL, whose coefficients change sign but are again insignificant. Only for specification I, which includes the special case of Germany, some results differ. We infer that our results are not crucially affected by the data manipulations that were necessary to obtain a workable time series for the number of retail outlets.

Finally, our conclusions regarding the effect of *EPL* may be premature. Given substantial manipulations necessary to obtain a complete time series (see appendix), and other measurement problems associated with the OECD *EPL* index (Blanchard and Wolfers, 2000), there are reasons to doubt the validity of the indicator used. In order to cross-check results, we replaced the *EPL* indicator with variables constructed using data from the *Social Reforms Database* of the Fondazione Rodolfo DeBenedetti. Amongst other information, this database provides a list of EPL reforms for all countries in our sample, and classifies them as flexibility-increasing or -decreasing.[15] From this information, we constructed two time series on the cumulative number of EPL reforms for each country. When replaced for our initial *EPL* indicator in specification II, these variables also yield insignificant results (available upon request).

5 Conclusion

Barcode scanning, a critical information technology in the retail sector, has diffused to different saturation levels across European countries. Econometric results based on data from various sources suggest that, as expected, this retail technology diffuses more intensely in countries with large and growing retail sectors and economies. It is therefore not surprising that the United States is ahead of most European countries when it comes to IT diffusion in the retail sector and the resulting productivity gains in the 1990s. With respect to an upcoming 'retail revolution' that relies on RFID technology, our results lead us to expect stronger RFID diffusion in countries that allow retailers to exploit scale effects. In line with classic theory, we also find that raising labor costs induce retailers to substitute barcode scanners for labor. In contrast, we do not find employment protection legislation to significantly impact retail IT diffusion.

[15] There is also a classification into marginal and structural reforms, but as most listed reforms are marginal we did not use this distinction. See `http://www.frdb.org/documentazione/scheda.php?id=55&doc_pk=9027` for more detail.

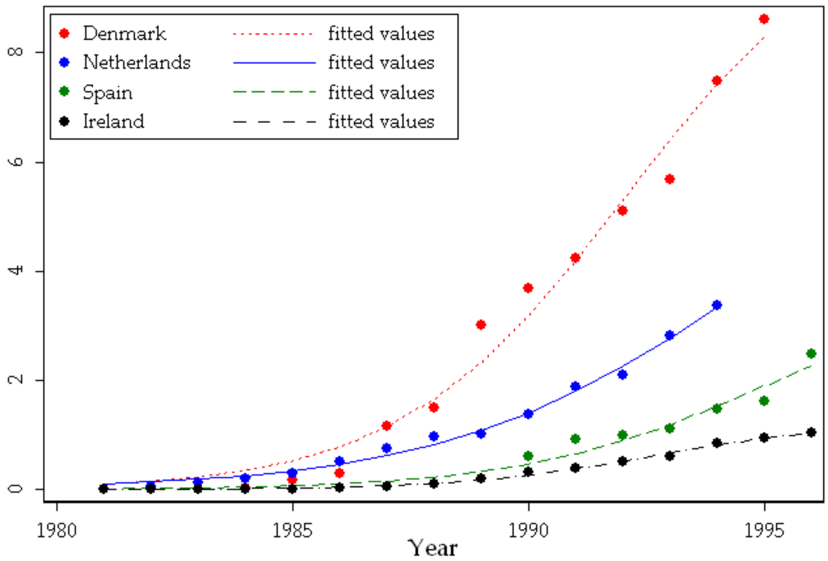
Our results concerning the impact of competitive intensity seem to differ with conventional wisdom. We find that the emergence of hypermarkets represents increased retail competition and that such competition reduces long-run retail IT diffusion. This effect, which is robust in a variety of specifications, has two potential explanations. First, hypermarket competition may very well cause exit of potential IT adopters, namely smaller-sized supermarkets. Second, hypermarkets – which are most likely to adopt barcode scanning early – discourage subsequent adoptions of rival retail formats. Overall, these results suggest that liberalisation of retail market entry and the associated emergence of hypermarkets deepens retail segmentation such that hypermarkets on the one hand and small down town retailing (including shopping mall retailing) prevail. In contrast, intermediate retail formats – in particular medium-sized supermarkets – are likely to suffer from market liberalization.

One should notice, however, that the productivity implications of these findings are not evident: depending on how much retail volume goes through barcode scanning retailers, IT productivity may increase even though aggregate IT intensity decreases. Also, our data are not directly comparable to measures of retail IT investments, since they count the number of barcode scanning stores, not the number of scanner installations. In our data, a smaller supermarket with, say, one scanner checkout has the same weight as a larger one with multiple scanner checkouts.

Further research may include measures of foreign direct investments in order to assess the role of large multinational retail firms in IT diffusion. Given data on the emergence of one-stop-shopping (e.g., motorization and demographics), it may also be possible to address the potential endogeneity of hypermarket development more rigorously. Finally, the present results are based on a rather small number of observations. It should be interesting to include more countries and explanatory variables. Reviewing our efforts to put together the present dataset, we however fear such a task is more demanding than it seems at first sight.

A Data appendix

Figure 2: Number of barcode scanning stores (in %, by country)



Scanning outlets. Data source are the statistical appendices of the European Article Numbering Association's (EAN) yearly reports for 1983 through 1997 (available at `www.ean-int.org`). They give the number of barcode scanning outlets per country for the years 1981 through 1996, although this period is not entirely covered for all countries. Data for Belgium include Luxembourg. In the cases of Austria, Denmark, Ireland and Spain, it was clear from the text in the country sections of the reports that the number of scanning outlets was zero before 1984, although it is reported as missing in the respective appendix table. Missing observations in the series for Italy (1982) and Ireland (1989) were replaced by linear interpolation using adjacent observations. Data for the last years of observation, 1995 and/or 1996, seemed inconsistent with data for preceding years in the cases of Austria, Italy and the Netherlands. They indicated either a decrease of the the number of scanning outlets (Netherlands, 1995; Italy, 1996) or an overly strong increase (Austria, 1995 and 1996).[16] In a telephone interview, we were told by German EAN representatives that collection of these data became increasingly difficult during the mid-1990s, as barcode scanners became standard technology, different types of scanner

[16]According to the original figures, the number of scanning outlets in Austria rose from 4,670 to 13,827 (hence by 300%) between 1994 and 1995. In relation to the total number of retail outlets in Austria, which *Euromonitor International* estimates at 38,546 for 1995, this would imply an increase in penetration from 12 to 36% in one year. We believe that the post-1994 figures refer to the number of scanner checkouts rather than the number of scanning outlets.

Table 7: Detailed summary of variables*

Variable	*OUT*	*HYP*	*EPL*	*WAGE*	*GDP*	*VOL*	*SUP*
Country							
Austria	4762.5	29.9	2.2	87.9	94.0	95.2	696.1
	356.2	15.6	.2	45.3	37.6	31.8	664.5
Belgium	4653.9	7.5	2.8	87.8	93.9	94.8	166.2
	677.1	1.7	.9	37.2	36.6	42.9	115.6
Germany	4652.7	22.7	2.9	91.9	93.9	94.2	102.9
	1937.8	11.6	.9	37.0	31.5	27.2	51.9
Denmark	6841.3	16.0	1.8	90.3	94.7	96.5	216.3
	896.8	8.0	.7	49.0	34.7	23.2	102.7
Spain	20730.4	4.0	3.4	93.7	92.8	100.0	192.2
	8573.0	6.6	.8	43.1	46.0	27.3	182.7
France	7159.5	15.3	2.8	93.6	95.5	98.4	86.7
	2380.6	11.7	.3	30.1	33.3	17.1	52.6
Ireland	9177.1	5.3	.9	92.7	91.1	100.0	35.1
	707.9	13.1	.1	68.3	99.0	74.5	24.4
Italy	16139.8	3.9	3.6	94.7	93.4	99.0	104.3
	6221.5	9.1	1.9	17.0	33.7	25.0	139.0
Nether-	5469.4	2.4	2.5	95.8	94.3	101.5	276.2
lands	652.0	1.5	.6	24.0	40.2	25.0	76.9
United	6740.1	3.4	.5	91.0	93.1	93.6	101.3
Kingdom	2564.8	4.6	.2	40.8	44.8	61.5	25.9

**SUP* is the number of supermarkets per mn. inhabitants (Source: Euromonitor). See table 3 for a full description of the other variables. Country-specific means in the first line, in the second line the difference between the maximum and the minimum value observed in the respective series (range).

were introduced and small firms were unwilling to answer questionnaires. Apparently for these reasons, the EAN stopped collecting these data after 1997. We interpreted the inconsistent post-1995 data for Austria, Italy and the Netherlands as a first sign of these difficulties and therefore excluded them from our sample.

Retail outlets. Data on the number of retail outlets were taken from various issues of "Retail trade international", a publication by market researcher *Euromonitor International*. Every issue provides country-specific data on the retail sector, mostly collected from official and industry sources (such as trade magazines) for five consecutive years. The latest available issue is Euromonitor (2002), which covers the years 1997-2001. However, earlier issues covering the late 1970s and the 1980s only provide figures for few single years. We therefore had to replace missing values by interpolation for the following observations: Austria, 1981, 1982, 1984-1987; Belgium, 1981, 1983, 1985, 1986, 1988, 1989; Denmark, 1982-1984, 1986; France, 1982, 1983, 1985-1987; Germany, 1981-1983, 1987, 1989, 1991; Ireland, 1981-1987, 1989-1991; Italy, 1982-194; Netherlands, 1981, 1983, 1985, 1986; Spain, 1981-1984, 1988; United Kingdom, 1981, 1983, 1985, 1989, 1991. For every country covered, not all time series published in the various Euromonitor issues were consistent in overlapping years of coverage. Most probably, this is due to varying (non-)inclusion of gas stations, automobile dealers and mobile retail outlets. We therefore used the most recent available series (Euromonitor, 2002) for absolute values and projected this series back to 1981 using the trends from preceding series.[17] Whenever two issues gave inconsistent figures for the same year, we used the figure from the more recent publication. This approach entails the implicit assumption that the outlet share of whatever type of retail format included (not included) in the Euromonitor (2002) figures but not included (included) in the earlier figures has remained constant over time. Then, our constructed time series reflect changes in the number of retail outlets accurately, and differences across countries regarding the inclusion of a certain retail format in the time series are accounted for in estimation by the country-specific coefficients.

Hypermarkets. Data on the number of hypermarkets were also taken from the *Euromonitor* publications cited above. The following missing values for single years have been replaced by interpolation: Belgium, 1982, 1983; Denmark, 1984; Ireland, 1991; Italy, 1985; United Kingdom, 1983. Missing values for Italy, 1987 and 1988, and the United Kingdom, 1981, were replaced by data from the European Commission (1997, p. 21-17, table 9), which are consistent with the Euromonitor data for subsequent years. In the cases of Austria, Belgium, Denmark, the Netherlands and the United Kingdom, the time series published in the various Euromonitor issues were not always consistent in overlapping years of coverage. This may be due to changes in original industry sources. In these cases, the series from Euromonitor (2002) was projected back, in a similar way than described for the outlets series, using trends from preceding series. In the cases of Denmark and Germany, the figures base on a different hypermarket definition, which considers as hypermarkets food retailers who also sell non-food items (as in the standard definition) and have more than 1,500 square meters of retail space (as opposed to 2,500 square meters in the standard definition).

[17] In the cases of Austria and France, the series covering the late 1980s did not overlap with the subsequent series. We therefore extrapolated the earlier series, using information for 1985-1988, to obtain a value for 1989 which we could compare with the 1989 value of the following series.

Supermarkets. The *Euromonitor* publications also include data on the number of supermarkets, but with many missing values. Moreover, supermarket definitions are not as comparable across countries as hypermarket definitions. For example, Austria defines as supermarkets stores with a retail space between 400 and 1000 square meters, whereas France and Spain defines as supermarkets stores with a retail space between 400 and 2,500 square meters but Spain only counts such stores as supermarkets that additionally have at least 5 checkouts (Euromonitor, 1989). We therefore used respective data only in an auxiliary regression (table 4). Before, we replaced the following missing values for single years by interpolation: Austria, 1984; Belgium, 1981-1982, 1987-1988, 1990-1991; Denmark, 1984, 1990-1991; Ireland, 1980-1987, 1989, 1991-1992; Netherlands, 1988; Spain, 1989-1990. Data for the Netherlands, 1980-1986, and the United Kingdom, 1980-1984, remain missing. In all cases except Denmark and Germany, the time series published in the various Euromonitor issues were not always consistent in overlapping years of coverage. In these cases, the series from Euromonitor (2002) was projected back, in a similar way than described for the outlets series, using trends from preceding series.

Employment protection legislation. The revised OECD indicator for employment protection legislation (EPL) is published by the OECD (2004) for three moments in time: the 'late 1980s' (1989), the 'late 1990s' (1998), and 2003. We followed Blanchard and Wolfers (2000) in order to construct a time series from these data: for the years 1990-1997, we replaced missing values by linear interpolation and we assumed that EPL has not changed significantly throughout the 1980s. The fact that the *Social Reforms Database* of the Fondazione Rodolfo DeBenedetti lists only three marginal EPL reforms prior to 1989 – two for France, 1986, and one for Italy, 1987 – reconfirms this assertion.

Sales volume. The OECD indicator of the volume of retail sales is not available for Spain, 1981-1990 and for Italy, 1981-1985. We constructed a comparable indicator using *Euromonitor* data on retail sales and data from the GGDC 60-industry database on retail value added deflators. For Italy and Spain, we used this indicator instead of the OECD indicator for the whole sample period.

Wages and hours worked. The GGDC database contains information on the number of persons employed, annual hours worked and labor compensation per employee, and a value deflator for the retail sector. Unfortunately, the number of retail employees – which excludes self-employed persons or family members – is not available for all countries. The total number of hours worked as well as our index of the deflated average hourly wage are therefore based on the number of persons engaged.

B Results for robustness checks

Table 8: Estimation results using population as denominator*

	Dependent variable: Number of barcode scanning stores			
Specification	(I)	(II)	(III)	(IV)
HYP	-101.797[b]	-98.111[a]	-96.814[a]	-82.775[a]
	(56.681)	(34.648)	(34.156)	(38.829)
*D*HYP*	143.195[a]	142.682		
	(68.168)	(146.656)		
EPL	-321.143[a]	50.255		212.352
	(134.152)	(216.056)		(320.688)
*HYP*EPL*				-30.843
				(26.711)
WAGE	-3.847[b]	4.886[b]	5.011[b]	4.800
	(2.196)	(2.873)	(2.766)	(3.047)
GDP	-2.692	14.088[a]	13.117[a]	14.299[b]
	(3.710)	(6.456)	(4.881)	(7.280)
VOL	9.592[a]	10.914[b]	11.837[a]	10.664
	(4.179)	(6.166)	(5.371)	(6.956)
Country excluded:	Ireland	Ireland Germany	Ireland Germany	Ireland Germany
Time span (max.)	1981-1996	1981-1996	1981-1996	1981-1996
Observations	130	115	115	115
Adj. R^2	.993	.993	.993	.993
Root MSE	550.7	545.6	540.3	544.1

*NLS estimates of equation 1 with equation 2 inserted, where N_t denotes population (in millions) instead of the number of retail outlets. Estimates for γ_i, β_i and τ_i omitted. Asymptotic standard errors in parentheses. Significance levels: [a] 95%, [b] 90%

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