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Books or Bullion? Printing, Mining and Financial Integration in Central Europe from the 1460s

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Abstract

This paper examines the role of the advent of printing and the mining boom in explaining financial integration in Central Europe from the 1460s. It finds that changes in liquidity were not a major determinant of financial integration, but the mining boom fostered financial links between the mining districts and the rest of the region. Printing promoted financial integration mainly because it triggered a fall in the costs of transmitting information rather than because it facilitated human capital formation or institutional change. The financial significance of the advent of printing was comparable to that of the mining boom.

1. Introduction

In the mid-1450s – the exact year is not quite clear –, the first ever European book printed with movable types appeared in the city of Mainz. In the following decades, printing workshops sprang up in rapid succession in almost all major and many minor European cities. According to recent estimates, by the end of the fifteenth century more than 12 million books had been published (Buringh and van Zanden, 2009: 417). A few years after the advent of printing, in the early 1460s, new deposits of silver ore were discovered at Schwaz in Tirol and at Freiberg in Saxony. Other discoveries followed: In 1470, silver was found in Schneeberg and two years later in Geyer, both places located in the aptly called 'Erzgebirge', the 'Ore Mountains' on the Saxon-Bohemian border. With the output of other mines in Germany, Bohemia and Upper Hungary likewise increasing over the following decades, silver mining experienced a boom that surpassed anything that had gone before (Laube, 1976: 22 ff.; Spufford, 1991: 363). The total yearly output of the

Central European mines is supposed to have grown between two and five times (Nef, 1952/87: 735; Miskimin, 1977: 32; North, 2001: 143).

At about the same time that these developments took place, the European economy in general, and commerce in particular, entered an age of expansion that lasted well over a century (cf. e.g. Braudel, 1953; Wallerstein, 1989: 68; Scribner, 1996: xi; DuPlessis, 1997: 47). While research commonly acknowledges, or at least implies, that this was no mere coincidence – that in one way or the other both the mining boom and the advent of printing supported the upswing in trade – there is as yet no agreement on how exactly they influenced commerce, still less on their relative importance. These are the issues we address in the present paper. We do this by quantitatively examining how printing and the mining boom influenced the integration of financial markets in the region where both factors originated: in Central Europe, that is, mainly in the Holy Roman Empire north of the Alps.

In fact, where this region is concerned there is a broad literature that links the commercial expansion that began in the 1460s to the mining boom. There are two pertinent views: On the one hand, historians claim that the increasing supply of silver (and copper) stimulated trade between the centres of the mining industry and the Netherlands, where Antwerp became the dominant European raw metal market (van der Wee, 1981: 79; Munro, 2001: 31 f.; Blanchard, 2009: 308 f.). On the other hand, the mining boom is assumed to have eased constraints that had held back European trade during the 'bullion famines', i.e. during periods of bullion scarcity from ca. 1390 to 1410 and 1440 to 1460 (Day, 1980/87; Nightingale, 1990; 1997; Hatcher, 1996): It allowed an increase in liquidity that oiled the wheels of commerce (Stromer, 1981; Munro, 1991: 120).

Strikingly, in the context of the commercial expansion the advent of printing has been much less researched. While historians regularly emphasise that printing with movable types was one of the main technological innovations of the pre-industrial era (e.g. Gimpel, 1977: 236; Mokyr, 1990: 49; North, 2001: 114 f.; Cipolla, 1980: 178 f.), there is little agreement on when, how, and why it affected economic activity. No-one denies that printing caused a dramatic drop in the cost of books (de Roover, 1953; Plant, 1974), but one of the few quantitative analyses of its wider economic consequences finds that given its small share in the total economy the overall benefits were negligible (Clark and Levin, 2001; Clark, 2001). By contrast, other studies stress how dynamic pre-modern book production was (Buringh and van Zanden, 2009), that printing implied declining costs of becoming literate for sixteenth-century merchants and craftsmen (Cipolla, 1969), and that human capital was a key element of early modern economic growth (Baten and van Zanden, 2008). Some go as far as to claim that the advent of printing led to an 'information revolution' (McCusker, 1997; 2005; North, 2001; Dudley, 2008). The fall in transaction costs caused by the publication of exchange rates and prices is emphasised by North (1991) for the early modern age as a whole, and by McCusker (1997; 2005) for the period from around 1540, when the Antwerp Exchange began publishing business journals. Printing and declining information costs are also associated with state formation (Innis, 1951/2006; Volckart, 2000b) – a process which Epstein (1994: 467 f.; 2000; 2001: 28) and Volckart (2002b; 2002a) see as a major cause of pre-modern economic growth.

As indicated above, in this paper we focus on the integration of markets. We thus follow an approach that allows us quantitatively to analyse the determinants of commercial developments without having to rely on data on trade flows, which are not available for our period and area. The core idea is that price data, which are better preserved, make it possible to apply the 'Law of one Price': As trade links develop and intensify or markets integrate, merchants exploit arbitrage opportunities, which implies that prices converge. As we analyse financial instead of goods markets, we do not use commodity prices but rather exchange rates between gold and silver currencies, which we relate to the fine gold and silver content of the coinage. On this basis, we calculate local gold-silver ratios that we then use in the same way as other market integration studies use, for example, grain prices (cf. Persson, 1999; Jacks, 2004; Özmucur and Pamuk, 2007; Bateman, 2007). As money had to be exchanged for all but local transactions, the behaviour of money markets followed that of long-distance trade. In addition, these markets were even more directly exposed to liquidity effects than commodity markets. At the same time, the particularly favourable weight-value ratio of money meant that they were more strongly influenced by information costs than virtually any other market. Money markets therefore provide a benchmark to assess the effect of printing on other markets.

In a recent analysis (Chilosi and Volckart, 2009), we find a marked increase in financial integration in Central Europe between 1400 and 1520 (see also Blanchard, 2001). What is more, integration accelerated from the 1460s and advanced mainly because new long-distance trade links developed, most obviously in the Rhineland. Our results thus support both the view that the second half of the fifteenth century was an age of commercial expansion, and the hypothesis that new trade routes between South Germany and the Netherlands played a key role in the revival of late medieval commerce. At the same time, however, they suggest that the significance of the mining boom may have been overstated: According to our results, the bullion famines of the decades around 1400 and 1450 hardly hindered integration; the corollary is that an increase in liquidity following the growth in mining output should have had a limited impact, too. Moreover, while we found evidence of stronger integration between South Germany and the Rhineland, there was little progress within South Germany itself. Finally, Threshold Autoregression Analysis suggests that advances in integration in the Rhineland after c.

1450 were mainly due to a fall in transport and transaction costs, rather than to an exogenous increase in trade. Printing, the growing importance of human capital and the reform of the Holy Roman Empire that increased its organisational effectiveness emerge among the factors that caused this fall in costs.

The present paper confirms that changes in the level of liquidity have a limited role in explaining the dynamics of financial integration. Proximity to the sources of silver tended to favour integration also during the bullion famines; in this respect, the mining boom had little effect. However, our analysis provides strong support to the claim that the mining boom led to the development of new trade links between the mining districts and the rest of Central Europe. In fact, the analysis finds a robust and significant link between the boom and integration between cities close to silver mines and other Central European cities. While these links tended to be comparatively weak in the early part of the century, they became particularly strong during the mining boom.

This is not to say that the advent of printing was irrelevant – on the contrary: The financial significance of printing was comparable to that of the mining boom. We estimate that printing of a new book was associated with an increase in the level of financial integration between two cities, which was almost as significant as the discovery of a new source of silver, if the ore was located about 200 kilometres from one of the cities in a mining district. There is evidence that the importance of printing, but not that of the size of the printing industry, increased with distance. We also find some evidence that printing increased the effectiveness of Imperial institutions only if the size of the printing output is taken into account. However, evidence that printing increased the relevance of human capital in explaining financial integration is strong and robust: University cities became better integrated than other cities only once printing presses had been established. The association between printing and human capital did become stronger when the printing industry grew, but the effect is observable even where the size of the industry was below average. These results confirm that printing began to matter for the economy earlier than usually acknowledged, and that to appreciate the consequences of information technology one needs to analyse how it affected other sectors of the economy. In addition, they imply that, at least in this early phase, printing influenced financial markets mainly because it triggered a fall in the costs of transmitting information, rather than because it facilitated human capital formation or institutional change.

2. Econometric Approach

As usual in market integration studies (Parsley and Wei, 2001; Toniolo et al., 2003; Trenkler and Wolf, 2005; Federico, 2007; Jacks, 2005), we investigate the causes of financial integration through panel data regression analysis. To measure integration we rely on levels of convergence in the value of bullion, as embodied in local gold-silver ratios. As indicated above, we calculate these ratios on the basis of exchange rates and information on the gold and silver content of the coinage. In order to improve the comparability of our data, we consider only those silver currencies that dominated transactions in the respective cities in our sample and the Rhinegulden that circulated everywhere. An example serves best to clarify our approach. Consider Basel in 1472. There, a transaction was recorded where 17,938 Rhineguldens were exchanged for £20,628 14*s*. of the local silver currency, the Pound Rappenmünze (Harms, 1910: 359). At that time, the Rhinegulden contained 2.697 grams of fine gold, while the Pound, being the sum of 60 'vierers' with 0.418 grams of fine silver each, equalled 25.106 grams of fine silver (Cahn, 1901: 85; Weisenstein, 2002: 106, 138). The transaction thus involved the exchange of 48,378.79 grams gold for 517,367.80

grams silver, or, in other words, a gold-silver ratio of 1:10.69. As the late Middle Ages were still an age of hard money (Day, 1980/87: 2) where spot exchanges dominated in the sources from our region, such ratios give a good impression of how the local supply of, and demand for, gold and silver developed.[1] Following the approach sketched in the introduction, we can use the absolute value of differences in the ratios between cities – the spreads – to measure financial integration: The smaller the spread, the greater the level of integration. Specifically, since in a few cases the spread is equal to 0, the dependent variable is the logarithm of the yearly means of the spreads of the gold-silver ratios between two cities plus 1.

Here we present a parsimonious specification, focusing on the variables that matter.[2] In particular, apart from eleven decade dummies we control for three monetary variables: DEBASEMENT, AUTONOMY and UNION. DEBASEMENT captures the effect of changes in the fine gold and silver content of the most important silver currencies used in our area. It is equal to the kernel trend of the sum of all such monetary alterations (that is, to the values of the polynomial trend of alterations shown in Chilosi and Volckart, 2009, fig. 2). Because monetary debasements – i.e. those that aimed for example at driving out underweight foreign coins – reduced transaction costs, they were closely associated with cycles of convergence of the gold-silver ratios (Chilosi

[1] To compute the gold-silver ratios used here, we made the following assumptions: first, unless specified otherwise, transactions were carried out on the spot; second, if not explicitly stated otherwise, the sources presupposed *argent le roi* and gold of corresponding purity as raw materials; third, consumers used the largest silver denominations available to pay for high-purchasing-power gold coins; fourth, after debasements, within the home territory, new money replaced old coins within one year, whereas abroad, adjustment entailed a time lag of one year; and, fifth, gold and silver coins suffered alike from wear and tear. For a detailed discussion of the rationale behind and the implications of these assumptions see Chilosi and Volckart (2009).

[2] The inclusion of further variables with statistically insignificant coefficients, such as whether the two cities spoke the same language or were connected by a road link, did not change the results of the analysis presented here.

and Volckart, 2009; 2010). AUTONOMY indicates if the two cities between which we measure the spread were autonomous with regard to monetary policies, as opposed to being subject to secular or ecclesiastic princes. Since urban governments found it easier to commit to monetary stability than princes, we expect this variable to be associated with fewer fiscally motivated debasements (Volckart, 2009; Chilosi and Volckart, 2010). Hence, in such cities the value of bullion should be more stable, and financial integration should be stronger. UNION indicates if the cities were part of the same currency union – a factor that has been found to promote financial integration (Boerner and Volckart, 2008). We also control for whether both cities were involved in war (WAR), as we expect this to cause disintegration. Transport costs are proxied by the distance in kilometres between two places (DISTANCE) and by whether they both have access to a river (RIVER) or a sea (SEA). Since in the course of the fifteenth century rivers became easier to use for transport, for example, because tow paths were constructed (cf. Ellmers, 2007: 175), we also allow RIVER to interact with YEAR.

As mentioned in the introduction, toward the end of the fifteenth century the Holy Roman Empire underwent a process of reform that substantially increased its organisational efficiency (Angermeier, 1984; Krieger, 2005). In the course of the reform, the Imperial diet – the Reichstag – developed into a forum that became increasingly effective in harmonising law and coordinating law enforcement. Cities, however, had always stood outside the feudal structure dominated by the princely courts (Heinig, 1988: 104 f.); as the Empire revived, their legally and socially inferior role became more economically relevant. The cooperation between emperors and estates that was coordinated at the Reichstag thus helped integration between the emerging territorial states far more than that between cities (Chilosi and Volckart, 2009). This is why we can capture the effect of the increasing effectiveness of the empire by introducing a dummy variable (STATE) that indicates if both cities, between which we observe a gold-silver ratio difference, were under the jurisdiction of a secular prince.[3] As we expect this factor to become significant in the later part of period under analysis, we also let STATE interact with MCDLX-MDXX, a dummy variable equal to 1 from 1461 onward.

This takes us to the factors in which we are primarily interested, i.e. to the mining boom and to printing and human capital. As for human capital, we use the existence of a university in both cities between which we observe gold-silver ratio differences as a proxy (UNIVERSITY). To capture the effect of printing, we employ two measures: first, a dummy indicating if there was a printing press in the two cities (PRINT), and second, an estimate of the total number of circulating book-editions in the two cities each year (CIRCULATION). The second measure allows us taking the size of the printing industry into account. Using these two measures makes it possible to check the robustness of the results. Lacking data on the size of print runs, we estimate book circulation on the basis of the number of editions published in the year, plus ninety percent of those published in the previous year, and so on. We drew the data from the British Library Incunabula Short Title Catalogue (http://138.253.81.72/~cheshire/istc/advanced.html), which contains the most comprehensive database of printed editions until the end of the fifteenth century currently available. As there is uncertainty about the number of publications edited in 1500, we interpolated the data from 1499 to 1520.[4] It would have been desirable to construct a per capita estimate

[3] Though ecclesiastical rulers were also in a position to benefit from imperial institutions, their inclusion may have had a confounding effect as clerical influence could limit capital mobility. In any case, only 10 of the over 5500 observations of spreads in our sample are between cities ruled by ecclesiastical princes. Restricting the analysis to secular princes therefore does not bias our results.

[4] The results on printing are robust against the exclusion of interpolated data, which however, help providing more reliable estimates for the other variables. The

of books circulation, but this is impossible as population data are available only for about half of the city-pairs (Bairoch et al., 1988; Lourens and Lucassen, 1997) and our approach requires large sample sizes to produce reliable results. There is a database on printed merchant manuals (Hoock and Jeannin, 1991) that could in principle have provided material for an ideal proxy of mercantile human capital. However, before the 1520s in our area such prints were published so rarely that the construction of a variable capturing their dissemination proved impossible (cf. Kaiser, 2001: 7 ff.).

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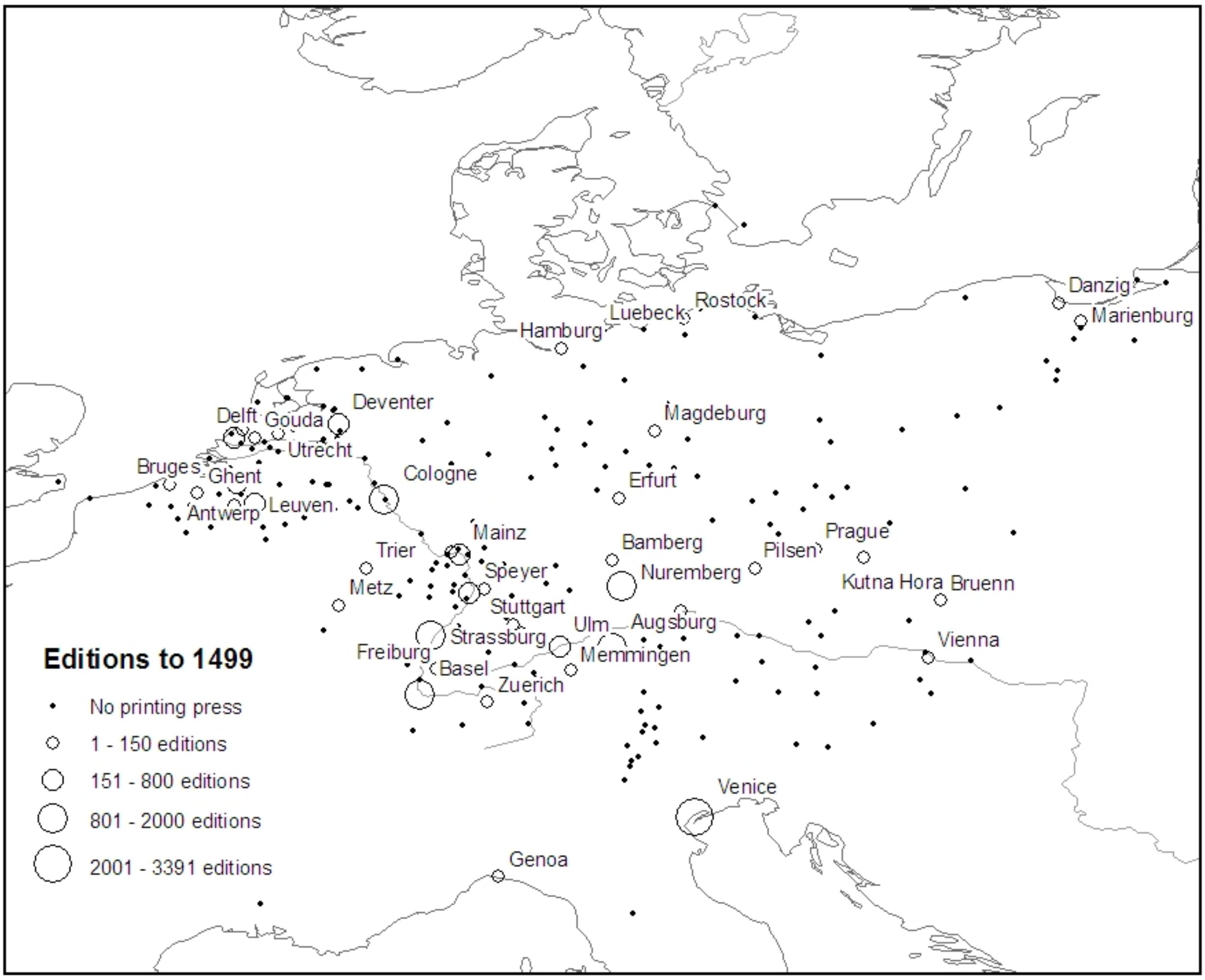
interpolation strategy proceeded as follows. Partly by nature, partly by design, the typical pattern exhibited by the circulation variable in each city involved a period of rapid growth at the beginning followed by slower growth in the final years of the century. The point when the trend stabilised was identified with the assistance of the Quandt-Andrews breakpoint test on the slope of a linear trend. The slope of the trend from that point onwards was used to construct an upper bound and the level a lower bound. The interpolated figure in each city is the average between the two. Using the upper or the lower bound did not alter the results. In a few cases the pattern diverged from the typical shape, and ad hoc interpolation was used.

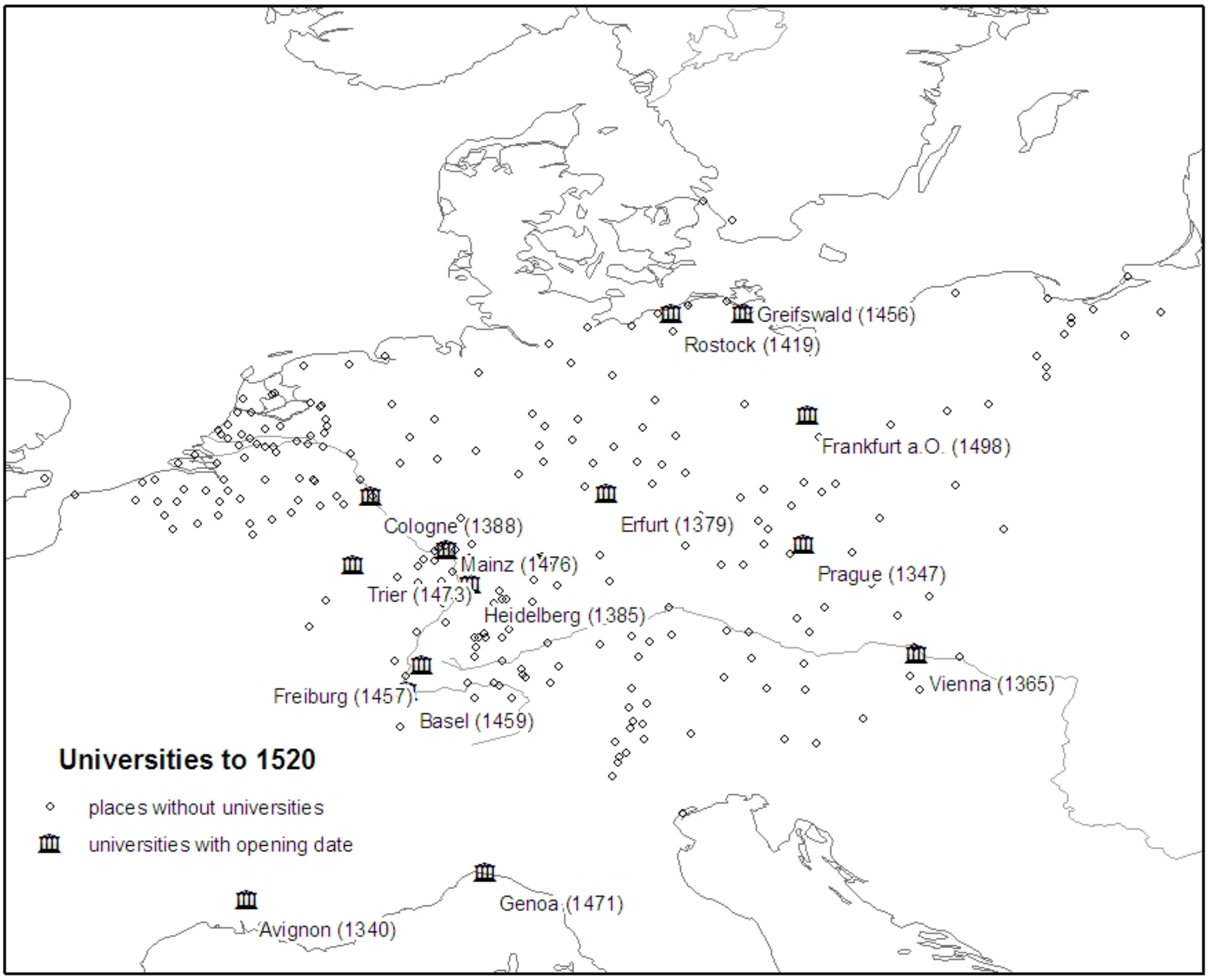
Figure 1: Book Editions Printed in the Cities in the Sample, to 1499



Source: British Library Incunabula Short Title Catalogue

Printing could help financial integration not only through the publication of merchants' manuals, but also through that of news-sheets with information on monetary standards, forgeries and exchange rates, as well as on wars and natural disasters (Haebler, 1907-08; Griese, 1996; 1997; Hoock and Jeannin, 1991: 351 ff.; Spufford, 2002: 54). Moreover, it supported the development of topical 'local knowledge' of distant places through printed chronicles, almanacs, calendars and political literature on foreign states, which typically included information on their economic and financial systems (cf. Westergaard, 1932: ch. 2). In all these fields we can expect it to have triggered a fall in information costs. Moreover, printing affected the level of these costs outside the immediate sphere of market behaviour, too. Information costs were politically relevant, influencing the effectiveness of the Holy Roman Empire and the states that began to form within its borders (for the role of information costs in state formation cf. Volckart, 2000a; 2002b: 146 ff.; on printing and late medieval state formation see Musson, 2004). To investigate the channels through which printing affected financial integration, we allow the printing variables to interact with UNIVERSITY, DISTANCE and MCDLX-MDXX*STATE. We use the first interaction to test if there was a synergy between human capital and printing, the second if printing led to a decline of information costs over long distances – i.e. in effect to a shrinking of distances –, and the third one if it increased the effectiveness of Imperial institutions. By comparing the interactions of the variables with PRINT and CIRCULATION, we explore how the size of the industry influenced the effects of printing.

Figure 2: Universities in the Cities in the Sample, to 1520

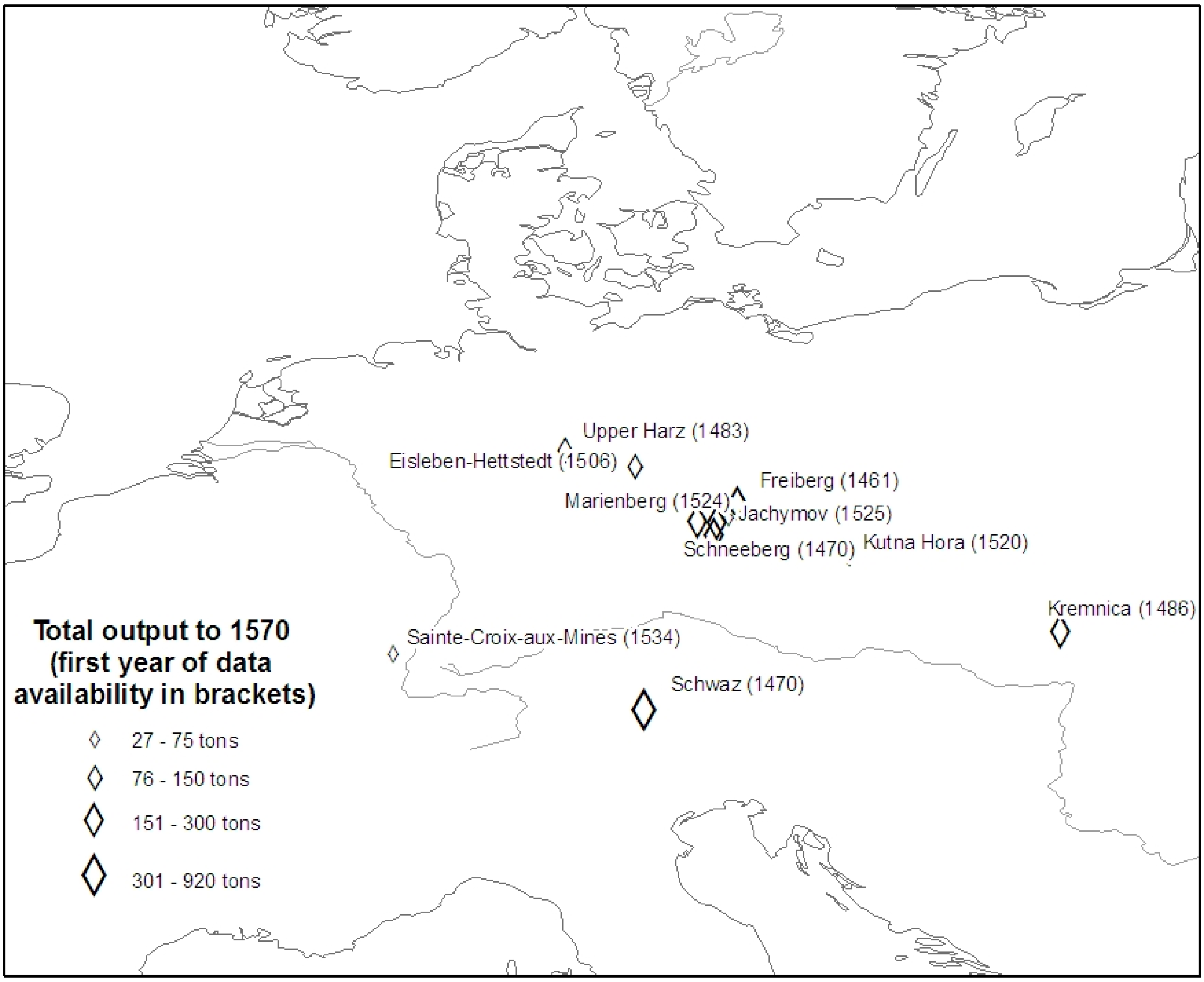


Source: Moraw (1989: 337).

To measure bullion availability we rely on six indices. Since Central Europe was principally producing silver, with much of the gold coming from Africa (Spufford, 1991: 289 ff.; Blanchard, 2005), we examine the two metals separately, and we expect availability of silver to be more important. The first index (GOLD and SILVER) is simply the sum of the inverses of the distance of each city from the principal mines of the area. For silver, we include Annaberg-Buchholz, Eisleben-Hettstedt, Freiberg, Marienberg, Schneeberg and the Upper Harz in North and Central

Germany, Jáchymov and Kutná Hora in Bohemia, Schwaz in Tirol, Kremnica and Nagy Banya in Hungary and Sainte-Croix-aux-Mines in Alsace; and for gold the mines of Kremnica, Nagy Banya and Sibiu which were all located in Hungary. By construction, the index increases when a new mine is discovered and decreases with the distance of each mine from a given city.

Figure 3: The Principal European Silver Mines, to 1570



Sources: See footnote 5.

An obvious drawback of the first index is that it does not take into account how productive each mine was. While, unsurprisingly, the available output data point to significant differences between mines, they are insufficient to estimate variations within mines over time.[5] For this reason, when we construct a second (GOLD_W1 and SILVER_W1) and a third index (GOLD_W2 and SILVER_W2), we weight the inverse of the distance from each mine by the average yearly mining output in tons. As a significant share of the available data refers to the period after the 1520s, when supply patterns began to be affected by large volumes of incoming bullion from the Americas, we use two weights: One based on data until the 1570s and one on data until 1520. Whereas the first one more accurately indicates the mines' overall productiveness, the second one is more representative of the period. To capture the obvious increase in silver mining output from the 1460s onwards, we allow SILVER to interact with MCDLX-MDXX; on this basis, we can investigate the impact of the mining boom. As the three indices discussed so far are based on a simple addition of our estimated bullion availability in both cities, they control for the effect of the aggregate bullion supplied to a city-pair. Thus, they capture the role of liquidity on dynamics of financial integration but leave open the question of whether the mining boom helped the development of trade links between cities near mines and other parts of

[5] Output data: Annaberg-Buchholz: Laube (1976); Eisleben-Hettstedt: Westermann (1971; 1972); Freiberg: Köhler (1956), Goerlitz (1928); Jáchymov: Schenk (1968), Sternberg (1837/1981); Kutná Hora: Munro (1991); Kremnica: Kazimír and Hlinka (1978); Marienberg: Bogsch (1933); Nagy Banya, Sibiu: Paulinyi (1981); Sainte-Croix-aux-Mines: Nef (1941); Schneeberg: Hahn (1932); Schwaz: Westermann (1986; 1988); Upper Harz: Soetbeer (1879-80). Estimates of the stock of gold and silver in Europe for any point in time are extremely speculative (cf. Flynn, 1978: 394). Braudel and Spooner (1967: 444 ff.) discuss three methods of estimation. One method suggests a negative stock; the second a stock that the authors consider implausibly low. The third method, for which Braudel and Spooner 'plead indulgence', provides an estimate of c. 3500 tons of gold and 37,000 tons of silver for the year 1500. Given that the inflow of African gold in the fifteenth century cannot be quantified with any degree of accuracy, analogous estimates for the period in which we are interested are impossible.

Central Europe. To test this hypothesis, the last three indices used in the analysis (MAX_GOLD and MAX_SILVER, MAX_GOLD_W1 and MAX_SILVER_W1, and MAX_GOLD_W2 and MAX_SILVER_W2) refer to the maximum level of bullion availability between the two cities, rather than to their sum.

Like Federico (2007), we take the logarithm to all controls except of YEAR, MCDLX-MDXX and the decade dummies, so that the estimated coefficient denotes pure elasticity. Put differently, the coefficient shows the approximate percentage change in the value of spread plus 1 when the value of the independent variable (before the logarithmic transformation has been carried out) increases by 1 percent. As with the dependent variable, in the cases of the dummies and CIRCULATION we add 1 before taking the logarithm. To compute the elasticity of the spread (as opposed to that of 1 plus spread), we use the following formula:

(1) $b^*(1+1/S)$,

where b is the estimated coefficient and S the value of the spread. In the case of CIRCULATION and the dummies 1 is added; therefore the formula is slightly different:

(2) $b^*[(X+XS)/(S+XS)]$,

where X is the value of the variable (otherwise the notation is as before). Examining elasticity allows directly comparing the financial significance of the various factors. However, the economic significance of a percentage change depends on the size of the controls, and for the dummies the interpretation of elasticity is not straightforward. To obtain the percentage change in the spread for a unit change in the dummy variable, we use the following formula:

(3) $100*(2^b-1)*(1+1/S)$,

where, again, b is the coefficient of the dummy variable and S is the value of the spread. The figures presented in the next section are based on the average spread: 1.840 grams of silver per gram of gold.

To limit the risk of multicollinearity, we centre all continuous variables involved in the interaction analysis (cf. Aiken and West, 1991) and control for time effects through decade dummies – an approach that has the additional advantage of being able to account for remaining non-linear features in the trend. The baseline coefficients of those variables for which we examine the interaction with other variables refer to the effect when the quantitative variables are equal to their sample mean[6] and the categorical variables equal to 0. To obtain the value of the coefficients for other values of the variable (or variables), with which they are interacting, we multiply the interaction coefficient (or coefficients) by the value of the centred quantitative variables and by log(2) for all dummy variables except MCDLX-MDXX (in which case we multiply it by 1), and then add it to the baseline coefficient.

Unavoidably, the composition of our sample is determined by the survival and accessibility of the sources. As such, it resembles a random sample of transactions taking place in fifteenth-century Central Europe. While this feature implies that a random-effects estimation is a suitable approach, the Hausman tests finds strong evidence of correlation between the city-pair effects and the covariates. Hence, random-effects analyses produce biased estimates. Given the high reliance on variables

[6] After the log transformations have been carried out, the sample means of the continuous variables involved in the interaction analysis are as follows: YEAR: 1466.250, DISTANCE: 5.692, CIRCULATION: 1.360, SILVER: -3.108, SILVER_W1: -1.913, SILVER_W2: -1.617, MAX_SILVER: -3.652, MAX_SILVER_W1: -2.445, and MAX_SILVER_W2: -2.111.

that are time-invariant (DISTANCE, RIVER and SEA) and rarely changing (AUTONOMY, UNION, STATE, and the indexes of bullion availability), the main alternative, i.e. fixed-effects estimation, is vulnerable to inefficiency. We therefore rely on a fixed-effects vector decomposition model (Plümper and Troeger, 2007). Finally, to estimate the coefficients we use a feasible generalised least squares estimator, as common shocks and different levels of transaction costs across city-pairs imply cross-section heteroskedasticity and contemporaneous correlation (Federico, 2007).

3. Books and Bullion

Tables 1 and 2 present the results of our analysis. For reasons of space, we do not present the constants, coefficients of the individual effects and the decade dummies. The first six specifications use the six different indices of bullion availability described above and control for printing with the presence of a printing press in both cities. The following six specifications are the same as the previous six, except for the inclusion of the interaction terms with PRINT. In table 2, PRINT is substituted by CIRCULATION.

Table 1: The Causes of Financial Integration: The Printing Press and the Mining Boom

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
DEBASEMENT	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***
AUTONOMY	-0.121***	-0.126***	-0.124***	-0.123***	-0.126***	-0.123***	-0.136***	-0.141***	-0.139***	-0.139***	-0.142***	-0.139***
UNION	-0.629***	-0.605***	-0.611***	-0.611***	-0.613***	-0.600***	-0.662***	-0.638***	-0.647***	-0.641***	-0.627***	-0.631***
WAR	0.526***	0.524***	0.524***	0.522***	0.524***	0.524***	0.529***	0.526***	0.526***	0.525***	0.527***	0.526***
DISTANCE	0.033***	0.032***	0.032***	0.033***	0.032***	0.033***	0.021**	0.021**	0.020**	0.024***	0.024***	0.024***
RIVER	-0.036*	-0.015	-0.025	-0.015	-0.014	-0.011	-0.035	-0.015	-0.025	-0.015	-0.012	-0.012
RIVER*YEAR	-0.003***	-0.003***	-0.003***	-0.004***	-0.004***	-0.004***	-0.002***	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
SEA	-0.306***	-0.289***	-0.309***	-0.283***	-0.276***	-0.278***	-0.309***	-0.292***	-0.313***	-0.288***	-0.283***	-0.285***
UNIVERSITY	-0.046	-0.051	-0.043	-0.042	-0.060	-0.029	0.203***	0.198**	0.206***	0.205***	0.185**	0.213***
PRINT	-0.106**	-0.119**	-0.113**	-0.119**	-0.120***	-0.126**	0.057	0.042	0.050	0.041	0.033	0.032
PRINT*UNIVERSITY							-0.677***	-0.673***	-0.676***	-0.670***	-0.662***	-0.657***
PRINT*DISTANCE							-0.141***	-0.135***	-0.137***	-0.132***	-0.132***	-0.128***
PRINT*MCDLX-MDXX*STATE							0.377	0.400	0.393	0.398	0.398	0.385
MCDLX-MDXX	-0.084	-0.041	-0.062	-0.051	-0.029	-0.030	-0.089	-0.047	-0.068	-0.057	-0.030	-0.038
STATE	0.105***	0.113***	0.108***	0.111***	0.108***	0.114***	0.109***	0.116***	0.112***	0.115***	0.116***	0.119***
MCDLX-MDXX*STATE	-0.161***	-0.154***	-0.157***	-0.152***	-0.151***	-0.156***	-0.153***	-0.148***	-0.150***	-0.147***	-0.144***	-0.150***
SILVER	-0.100***						-0.097***					
MCDLX-MDXX*SILVER	0.120***						0.119***					
SILVER_W1		0.002						0.003				
MCDLX-MDXX*SILVER_W1		-0.095***						-0.088***				
SILVER_W2			-0.038***						-0.038***			
MCDLX-MDXX*SILVER_W2			-0.0186						-0.012			
MAX_SILVER				0.013**						0.010		
MCDLX-MDXX*MAX_SILVER				-0.125***						-0.111***		
MAX_SILVER_W1					0.020**						0.029***	
MCDLX-MDXX*MAX_SILVER_W1					-0.117***						-0.137***	
MAX_SILVER_W2						0.030**						0.026**
MCDLX-MDXX*MAX_SILVER_W2						-0.142***						-0.128***
GOLD	0.021						-0.015					
GOLD_W1		0.020						-0.011				
GOLD_W2			0.020						-0.014			
MAX_GOLD				0.022						-0.011		
MAX_GOLD_W1					0.023						-0.010	
MAX_GOLD_W2						0.020						-0.012
Adjusted R-squared	0.591	0.591	0.591	0.591	0.591	0.591	0.593	0.593	0.593	0.592	0.593	0.593
N	5606	5606	5606	5606	5606	5606	5606	5606	5606	5606	5606	5606

Key: N=sample size; *=significant at the 10 percent level, **=significant at the 5 percent level, ***=significant at the 1 percent level.

Table 2: The Causes of Financial Integration: Circulation of Books and the Mining 1460-1520

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
DEBASEMENT	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***
AUTONOMY	-0.099***	-0.105***	-0.102***	-0.102***	-0.106***	-0.102***	-0.111***	-0.117***	-0.114***	-0.115***	-0.118***	-0.115***
UNION	-0.638***	-0.605***	-0.618***	-0.620***	-0.604***	-0.608***	-0.678***	-0.650***	-0.661***	-0.654***	-0.639***	-0.644***
WAR	0.517***	0.515***	0.515***	0.513***	0.516***	0.515***	0.520***	0.518***	0.518***	0.516***	0.519***	0.519***
DISTANCE	0.033***	0.032***	0.032***	0.032***	0.032***	0.032***	0.019**	0.018**	0.017**	0.022**	0.022**	0.022**
RIVER	-0.022	-0.015	-0.010	0.000	0.004	0.003	-0.018	0.003	-0.007	0.005	0.008	0.008
RIVER*YEAR	-0.003***	-0.003***	-0.003***	-0.003***	-0.004***	-0.004***	-0.002***	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
SEA	-0.326***	-0.308***	-0.332***	-0.302***	-0.299***	-0.301***	-0.316***	-0.230***	-0.322***	-0.293***	-0.289***	-0.291***
UNIVERSITY	-0.021	-0.034	-0.023	-0.025	-0.046	-0.016	0.316***	0.312***	0.320***	0.323***	0.305**	0.335***
CIRCULATION	-0.035***	-0.036***	-0.035***	-0.036***	-0.037***	-0.036***	-0.024***	-0.025***	-0.024***	-0.025***	-0.025***	-0.025***
CIRCULATION*UNIVERSITY							-0.100***	-0.103***	-0.102***	-0.103***	-0.104***	-0.104***
CIRCULATION*DISTANCE							0.003	0.002	0.002	0.003	0.003	0.003
CIRCULATION*MCDLX-MDXX*STATE							-0.045**	-0.043**	-0.044**	-0.043**	-0.043**	-0.043**
MCDLX-MDXX	-0.081	-0.035	-0.059	-0.046	-0.016	-0.027	-0.112	-0.067	-0.090	-0.076	-0.048	-0.057
STATE	0.095***	0.104***	0.097***	0.102***	0.103***	0.105***	0.091***	0.099***	0.095***	0.109***	0.099***	0.102***
MCDLX-MDXX*STATE	-0.181***	-0.154***	-0.177***	-0.172***	-0.168***	-0.175***	-0.146***	-0.137**	-0.141***	-0.135**	-0.133**	-0.140***
SILVER	-0.112***						-0.107***	0.002	-0.043***	0.014*	0.033***	0.029**
MCDLX-MDXX*SILVER	0.140***						0.132***	-0.097***	-0.011	-0.127***	-0.152***	-0.141***
SILVER_W1		0.000										
MCDLX-MDXX*SILVER_W1		-0.097***										
SILVER_W2			-0.046***									
MCDLX-MDXX*SILVER_W2			-0.009									
MAX_SILVER				0.006								
MCDLX-MDXX*MAX_SILVER				-0.116***								
MAX_SILVER_W1					0.030***							
MCDLX-MDXX*MAX_SILVER_W1					-0.151***							
MAX_SILVER_W2						0.024**						
MCDLX-MDXX*MAX_SILVER_W2						-0.136***						
GOLD	0.024						-0.009					
GOLD_W1		0.022						-0.005				
GOLD_W2			0.023						-0.009			
MAX_GOLD				0.024						-0.006		
MAX_GOLD_W1					0.020						-0.005	
MAX_GOLD_W2						0.022						-0.008
Adjusted R-squared	0.593	0.593	0.593	0.593	0.593	0.593	0.594	0.594	0.594	0.594	0.594	0.594
N	5606	5606	5606	5606	5606	5606	5606	5606	5606	5606	5606	5606

Key: N=sample size; *=significant at the 10 percent level, **=significant at the 5 percent level, ***=significant at the 1 percent level.

Considering that the panels are heavily unbalanced, subject to measurement errors and rely heavily on proxies, the adjusted R-square values signal a very good fit. Moreover, almost all coefficients have the expected sign. All the controls for monetary institutions, WAR, and all the controls for transport costs except RIVER have the expected sign and are highly significant – mostly at the 1 percent level, and at the 5 percent level otherwise. In the case of RIVER, the lack of significance and a consistently negative sign reflect the fact that access to a river became an important asset only in the course of the fifteenth century, when tow paths were constructed and rivers became easier to use. This is signalled by a negative and highly significant interaction coefficient with time. The analysis also confirms that states governed by secular princes, while being initially comparatively weakly integrated, became better integrated from the later fifteenth century. Before the 1460s, spreads between cities in secular states were on average between c. 7 and 13 percent larger than in other cities, and in the later period between 2 and 6 percent smaller. The latter figures correspond to a difference of between 0.055 and 0.164 grams silver per gram gold.

While the coefficient of UNIVERSITY is negative under all basic specifications (i.e. without interaction with printing), it is never significant. By contrast, under the same specifications the coefficients of printing are always negative and highly significant. When we use PRINT, the statistical significance is 5 percent or less. When we take the size of printing output into account, thus measuring the effect of printing more precisely (albeit less accurately), the coefficients are always significant at the 1 percent level. The financial significance of the printing press was greater than that of secular states: Spreads between cities with printing presses were between about 11 and 13 percent smaller than those between other cities. Put differently, establishing a printing press caused an average decrease of the spreads of between 0.201 and 0.237 grams silver per gram gold. The magnitude of the absolute value of the coefficient of CIRCULATION is close to that of distance; the basic specifications agree in placing the figure in the order of 0.036. In other words, in a city-pair with an average level of circulation (i.e. about 50 book-editions) an increase by one book-edition circulating during the year can on average be expected to be associated with a decrease in the spread of approximately 0.002 grams silver per gram gold.

Regarding the channels through which printing affected financial integration, the evidence that it facilitated the transmission of information about distant places is inconsistent. There is strong evidence that printing presses as such became more important as distance increased: The interaction coefficient is consistently negative and highly significant. However, these results do not hold when we take the size of their output into account, using the CIRCULATION variable. This suggests that news-sheets with financial information, which could be produced even by small and poorly equipped workshops that were not up to printing whole books, were more important for long-distance financial integration than merchant manuals with information on geographical and economic conditions abroad, whose production required large workshops with a sophisticated equipment and a generally larger output. Conversely, there is evidence that the effectiveness of imperial rule increased thanks to printing only when we take the size of the printing output into account, the interaction coefficients between MCDLX-MDXX*STATE and CIRCULATION being negative and significant at the 5 percent level. This result indicates that insofar as the advent of printing contributed to the revival of Imperial institutions, this was mainly the case in large centres. Elsewhere printing was rarely used to record or publish legal and administrative information relevant for the Empire’s effectiveness.

Figure 4: News-sheet Warning Against Counterfeit Guldens, Anton Sorg's Printing Workshop, Augsburg, c. 1482

Hie seind zemercken die zeichen der falschen gul
din im nyderland gemacht · vnd seind etlicher
müntzer zů Göttingen in Sachsen vnd in an
dern stetten verprannt vnd auf vier thumen
von im gemüntzet.

¶ Ite die guldin auff d vier herrn
schleg mit einem zwifaltigen · w ·
das steet oben an dem mentzer rad
ist falsch ·

¶ Die guldin mit einem apfel auf
einer seytē vñ sant johannes auff
der andern seyten ein schilt mit ey
nem leo · etlich seind falsch.

¶ Die guldin mit einem apfel auf
einer seyten · vnd die ander seyten
sant Peter mit einem steern an der
prust söl steen sant johannes auf
den Hamburger schlag ·

¶ Die guldin mit dem bischof mit
einem grossen schilt · vñ obē an dē
haubt ein · b · mit einem dittel auff
den kölnischen schlag ·

¶ Die guldin mit einē apffel auff
einer seyten vñ ein creücz mit einē
steren die ander seitē zwischen den
füssen auff franckfurter schlag seid
etlich falsch ·

¶ Item die vorgenannten guldin ist einer nit besser dann
fünff weyßpfenning · vñ ist der raiff vmbher guldin eins
halben halms dick · vñ das corpus ist gantz küpfferin vñ
übergült ·

¶ Vnd das kupffer ist so hörtt gemüntzet vnnd gesotten
das es wol clingt · darumb mag sy niemād erkennen an
dem clanng oder an dem strich ·

The news-sheet refers to counterfeit guldens produced in Göttingen, a place in North Germany c. 360 kilometres from Augsburg. Our analysis suggests that it was primarily such news-sheets that had an impact on long distance financial integration, rather than merchant manuals and similar publications. Source: Griese (1997).

The results show that both in terms of statistical and financial significance printing was a more important determinant of financial integration than human capital. Specifically, the interaction analysis shows that before the advent of printing human capital was of limited importance, indicating that by itself, any increase in human capital provoked by printing was insufficient to significantly improve financial integration. In fact, universities without printing presses appear to have been a liability rather than an asset, the baseline coefficients being uniformly positive and significant at the 5 percent level or less. This suggests that in the absence of printed material, literate and numerate persons had few chances to make use of their skills on financial markets even if they were university-educated. At the time universities mainly aimed at training lawyers and theologians who were in demand at the many princely courts in Germany (Moraw, 1989: 337). Hence, they proxy also for clerical influence; this factor may have impeded financial transactions insofar as it implied that the Canonical ban on usury and similar institutions were more strictly enforced.

However, there is robust evidence of a synergy between human capital and printing. Highly significant and negatively signed interaction coefficients show that as printing made potentially valuable financial information more readily available, the ability to exploit this became key. Even if a university was not necessary for CIRCULATION to have a highly significant association with financial integration, the difference remains striking. In the absence of printing presses, spreads between places with universities were between c. 21 and 25 percent larger than between others; when there were printing presses, by contrast, they were between c. 24 and 27 percent smaller. While medium-distanced cities with printing presses were not significantly better integrated than their counterparts without them, their spreads were on average 39 percent smaller if they were university cities.[7] The interaction between UNIVERSITY and CIRCULATION shows that the association between printing and human capital became stronger as the size of the industry increased, pointing to network effects (cf. Dudley, 1999). This result also supports the claim that spreading financial information was the principal means through which printing affected financial integration. In fact, unlike human capital, information has public good characteristics, being subject to non-rivalry in consumption and often costly exclusion (Stiglitz, 2000: 1148). Such features were particularly relevant when it was deliberately placed in the public domain, as it was the case with news-sheets. Still, even printing workshops whose output was below average were sufficient to turn universities into an asset. The average level of circulation in a city-pair with at least one printing press was about 150 book-editions, but the critical mass needed to make a difference to integration was about 70 to 100 book-editions. Hence, on the one hand, differences between large and small financial centres became more pronounced as a result of printing. This dynamic helps to illuminate the Central European process of financial concentration in the fifteenth century detected by Chilosi and Volckart (2009). On the other hand, however, printing allowed wider sectors of the population to engage in financial speculation also in small centres – a finding that matches Innis' (1950/2007: 170) claim that accessibility of information fostered the growth of new centres of finance.

Turning to bullion availability, there is unsurprisingly little evidence that proximity to gold mines favoured financial integration. The coefficient is never significant, regardless of which measure we use. It is negative only under nuanced specifications, when the interaction terms with printing are included. Silver tells a more interesting story. Both the un-

[7] The figures are computed neglecting the statistically insignificant effect of the interaction with STATE, and therefore, strictly speaking, they refer specifically to the case when the two cities are not both under the rule of a secular feudal lord. Otherwise the effect is somewhat lower.

weighted index and the second weighted index (i.e. the one where we weight the inverse of the distance from each mine by the average yearly mining output in tons up to 1520) detect that proximity to silver mines on the part of both cities favoured financial integration before the mining boom. The coefficients of the indexes are consistently negative and significant at the 1 percent level. Though the result is not confirmed by the other index, it points to the existence of financial links between the mining areas, suggesting that regions such as South Germany, which enjoyed advanced levels of integration early on, were not exceptional. In South Germany, cities like Augsburg and Nuremberg had become wealthy long before the mining boom began. Their prosperity involved substantial investment in nearby urban and rural industries, which implied a high level of regional financial integration (Ammann, 1970: 194; Stromer, 1978: 31 ff.). In the mining districts of Saxony, Tirol or Upper Hungary similar factors played a role. There, investors tended to spread their risks among a number of mines and over a relatively large geographical area, likewise promoting financial integration (Bogsch, 1966: 56; Westermann, 1997: 58).

As our previous analysis (Chilosi and Volckart, 2009) suggests, financial integration was inelastic with respect to overall levels of silver availability. The rise in the money supply following the growth in mining output during the boom had a limited impact on the dynamics of integration between cities near mines, where liquidity increased most. Indeed, in sharp contrast to the predictions of the liquidity hypothesis, the interaction coefficients are positive and highly significant when we neglect the size of the output of the mines. Then, the elasticity of the spread with respect to overall levels of silver availability during the boom becomes slightly positive. Though the interaction coefficients are negative when we use the weighted indices, they are significant only with the first weight. During the mining boom, the estimated elasticity of the spreads tended to increase but remained on the whole relatively small: The means of the coefficients show that before the boom, an increase in silver availability of 1 percent caused a change in the spread of on average -0.160, -0.039, or -0.063 percent, depending on which index we choose. During the boom these figures become 0.037, -0.142, and -0.083 percent.

There is, however, strong and robust evidence that the mining boom strengthened financial links between cities close to mines and other cities in Central Europe, showing that the fortune of the mining districts depended crucially on how productive the mines were. Thus, before the mining boom – in the age of bullion famines –, these financial links tended to be comparatively weak. Conversely, during the boom they became particularly strong. In fact, the coefficients of MAX_SILVER, MAX_SILVER_W1 and MAX_SILVER_W2 are always positive and mostly significant at the 5 percent level or less. This changed radically during the boom. The interaction coefficients with MCDLX-MDXX are negative and significant at the 1 percent level under all the specifications and using all measures; their magnitude implies that the elasticity becomes negative. The financial significance of being close to a mine increased dramatically from the 1460s onwards. The magnitude of the absolute value of the elasticity increased by about four times or more, as compared to before the boom. The average elasticity before the boom is 0.017, 0.043 or 0.042, depending on the index. After the boom it is -0.168, -0.171 and -0.169. These estimates imply that the opening of a new mine c. 200 kilometres from a city in the mining district caused an average decrease in the spread with other cities by about 0.003 grams of silver per gram of gold[8] – a figure that is remarkably close to that associated with the printing of a new book.

[8] The averages of the indexes are 0.400 mines per kilometre, 2.113 ton*mines per kilometre and 2.046 ton*mines per kilometre (note that the magnitude of the figures reflect the fact that the sample includes cities located less than 1 kilometre from a mine). The average annual mining output of a mine is 3.869 tons for the first weight

4. Conclusion

This paper finds that both the advent of printing and the mining boom mattered for the increase in financial integration experienced by Central Europe from the 1460s. The analysis confirms that printing began influencing economic activity earlier than usually assumed**.** From the perspective of financial integration the advent of printing entailed sudden rather than gradual changes. It was specifically news-sheets with financial information, which given their low cost were produced also by small printing presses, rather than merchant manuals or books with information on the geographical and economic context of distant localities that mattered for long-distance financial integration. By contrast, insofar as the advent of printing contributed to the revival of Imperial institutions, this was mainly the case in large centres. There is strong and robust evidence of a synergy between printing and human capital. The advent of printing was a necessary condition for university cities to become comparatively better integrated. Like today, the economic significance of human capital in the late Middle Ages depended on information technology.

Unsurprisingly, there is little evidence that proximity to gold mines favoured financial integration. Silver, however, was a different matter. There is evidence that cities close to a mine began to integrate before the mining boom began. In this respect, the boom itself had a limited effect: Cities that were better placed to benefit from the growing liquidity once the output of silver had begun to increase experienced no significant advance in financial integration. Changes in liquidity levels thus do not emerge as a significant determinant of financial integration. There is, however, strong and robust evidence that the mining boom strengthened financial links between cities in the mining districts, whose fortune was inextricably linked to the productivity of the mines, and other cities in

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and 4.333 for the second one. Hence the estimated distances of a new mine needed to increase the values of the indexes by 1 percent are 250, 183 and 211 kilometres.

Central Europe. In fact, these financial links tended to be comparatively weak in the first half of the fifteenth century, and became significantly stronger during the mining boom.

The advent of printing had a comparable financial significance as the mining boom, highlighting that we need to analyse the effects of information technology on other sectors of the economy to appreciate its significance. The question remains what our analysis implies for other markets. Financial integration implied increased homogeneity and stability of the value of bullion, less persistent local gold or silver shortages and lower transaction costs. In principle, we expect the mining boom to affect the money market in a similar way to other markets of goods traded over long-distances. If anything liquidity issues should influence money markets more directly. One crucial difference, however, is that the weight-value ratio of specie-based commodity money was more favourable than that of practically any other good that was regularly traded. Transport costs, though being of course positive, affected the integration of financial markets therefore less than that of other markets for other commodities. Conversely information costs played a comparatively larger role. Hence, future research needs to systematically examine the extent to which our results can be generalised for the real economy.

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