Financial Development and Technology Diffusion

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October 2014

Motivation

- **There are humongous differences income per capita between rich and poor countries that have emerged during the last 200 years.**
- **The Great Income Divergence is a consequence of a divergence in the rates of adoption of new technologies (Comin and Mestieri, 2014).**
- **Evidence that financial development is correlated with productivity growth (Rajan and Zingales, 1998, Guiso, Sapienza and Zingales, 2003)**
- **Possible mechanisms: capital markets**
  - improve allocation of capital among investment opportunities
  - reduce barriers to entry
  - Improve efficiency of product markets

Is domestic financial development an important barrier to technology diffusion?

- **Why is this an interesting question:**
  - The critical driver of productivity is technology
  - And whether and how intensively new technologies are adopted matters much more for the cross-section than whether technologies are invented
- **Existing work**
  - Availability of finance impacts Innovation (Kortum and Lerner, other work on VC)
  - Some prior work on innovation based on case studies
  - Much work focused on investment (in physical capital) and the necessity to use external funds (Rajan and Zingales and similar for SMEs)
- **Technology is different on some important dimensions**
  - Harder to distinguish a “good” idea from a “poor” idea ex ante (e.g. 60% of venture backed firms are terminated below cost)
  - Much greater focus on experimentation which make the decisions of how and when to use the new technology much more uncertain
  - Looking at the link between finance and technology diffusion provides a more direct test of the mechanism of Schumpeterian creative destruction

Is domestic financial development an important barrier to technology diffusion?

- Several challenges
- Data on technology diffusion has been scarce until recently
- Financial markets may be endogenous to development
- More generally, there are cross-country factors that affect both technology and financial market development (e.g., institutions, income, government activities, openness,…)

Our Approach

- **Look at the intensive margin of technology adoption across major technologies over last 130 years**
  - Technologies such as Railways, Motor Cars, Telegraph, Telephone, Steel, Radio, Computers, cell phones, and Internet)
  - Focus on intensive margin is partly driven by data availability (don't know exact date when technology arrived) and partly by the fact that other factors may be far more important in initial adoption (geographic and cultural differences, etc)

- **Look at the importance of finance in impacting the relative speed of diffusion**
  - Look at more vs. less capital intensive technologies
  - Look at periods closer to the invention relative to later

- **Some advantages of our approach**
  - Allows us to look longer time periods (going back to 1870 rather than 1960)
  - Potentially "cleaner" identification strategy that is discussed in greater detail later

Agenda

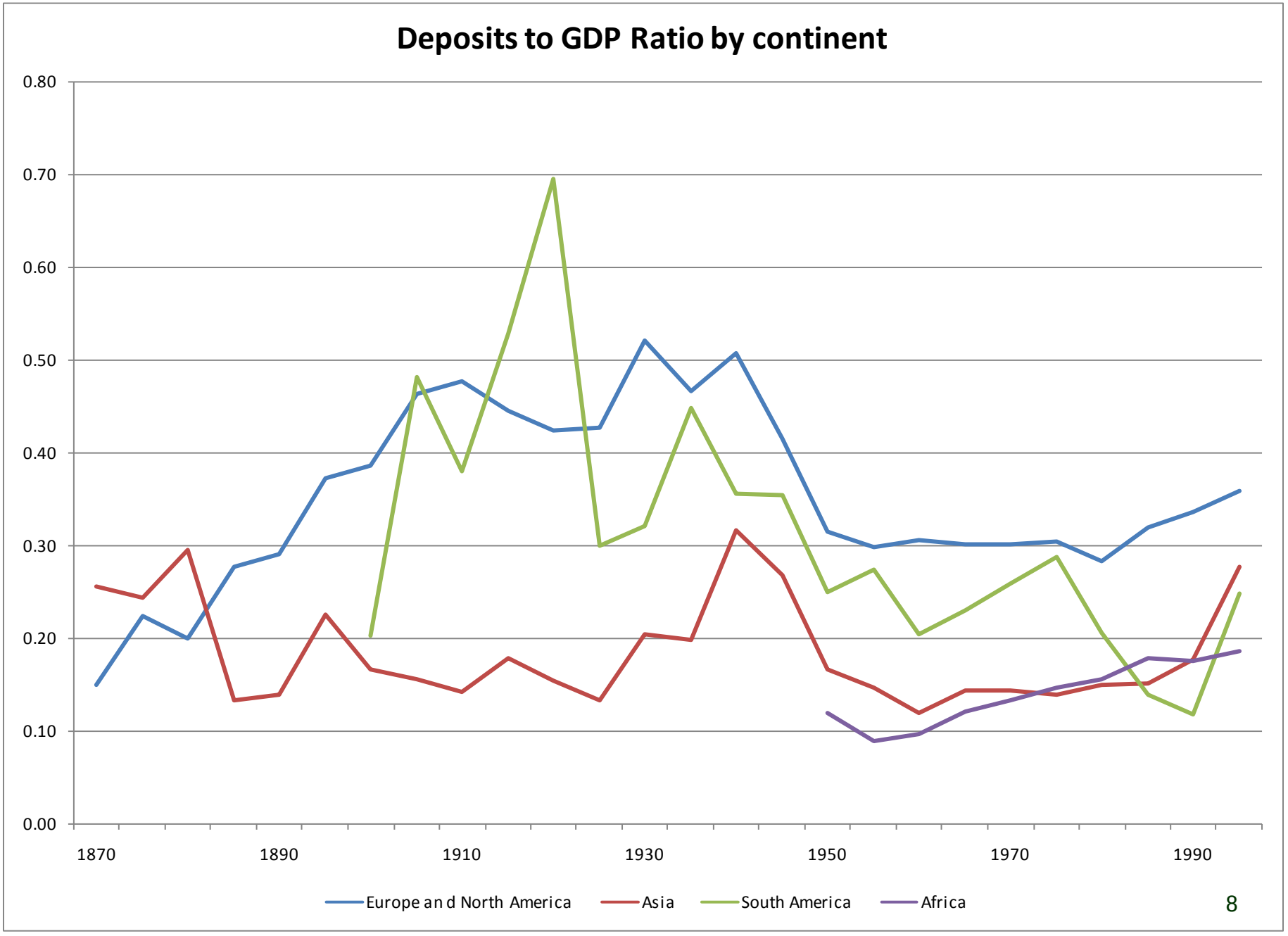
I. **Data and Identification Strategy**

II. **Results**

III. **Conclusions**

Descriptive Statistics on Technologies

	Technology	Capital Intensity	Countries covered		Country-Years per technology	
			Full Sample	*Europe & N. Am*	*Full Sample*	*Europe & N. Am*
1	Railroad track	High	34	18	183	131
2	Telegram	High	35	17	275	156
3	Telephone	High	54	19	631	318
4	Electricity Production	High	53	18	628	285
5	Electric Arc Steel	High	47	18	291	165
6	Blast Furnace Steel	High	35	17	156	87
7	Cell Phones	High	53	19	137	59
8	Ring Spindle	Low	32	12	170	63
9	Loom	Low	46	18	81	20
10	Passenger Cars	Low	54	19	599	277
11	Trucks	Low	53	18	575	268
12	Tractors	Low	52	18	263	103
13	Radio	Low	54	18	518	212
14	TV	Low	55	19	422	167
15	Computers	Low	53	19	138	56
16	MRI machines	Low	23	18	59	51
	Total				5,126	2,418


Deposits to GDP Ratio by continent
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1870
1890
1910
1930
1950
1970
1990
Europe an d North America
Asia
South America
Africa

Estimation Strategy

$$y_{ict} = \varphi_c + \gamma_{it} + \beta_1 \boldsymbol{X}_{ct} + \beta_2 \boldsymbol{FIN}_{ct} +$$

$$\beta_3 (\boldsymbol{FIN}_{ct} * \boldsymbol{DEP}_i) + \varepsilon_{ict}$$

Estimation Strategy

$$y_{ict} = \varphi_c + \gamma_{it} + \beta_1 \boldsymbol{X}_{ct} + \beta_2 \boldsymbol{FIN}_{ct} +$$

$$\beta_3 (\boldsymbol{FIN}_{ct} * \boldsymbol{DEP}_i) + \varepsilon_{ict}$$

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Financial Depth and Technology Diffusion Across 60 Countries: 1870-2000

Dependent Variable is Log of Technology Diffusion per Capita

	Full Sample	*Full Sample*	*Above Median Bank Deposits / GDP*	*Below Median Bank Deposits / GDP*	*Above Median Bank Deposits / GDP*	*Below Median Bank Deposits / GDP*
Deposits/GDP X capital intensity	0.424***	0.508***	0.402*	0.135	0.441**	-0.866
	(0.120)	(0.110)	(0.210)	(2.220)	(0.187)	(2.162)
Deposits/GDP	0.340***	0.137	0.104	1.383	0.0800	1.735*
	(0.120)	(0.110)	(0.140)	(1.010)	(0.149)	(0.938)
Human Capital		0.172	0.387**	0.248	0.199	-0.0281
		(0.110)	(0.160)	(0.440)	(0.260)	(0.495)
GDP per Capita		1.176***	1.340***	1.169***	1.383***	1.120***
		(0.052)	(0.250)	(0.170)	(0.370)	(0.191)
Human Capital x capital intensity					0.447	0.628
					(0.409)	(0.414)
GDP per capita x capital intensity					-0.0726	0.199
					(0.312)	(0.196)
Technology X Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5126	5126	3153	1973	3153	1973

Financial Depth and Technology Diffusion Europe and North America: 1870-2000

Dependent Variable is Log of Technology Diffusion per Capita

	Full Sample	*Full Sample*	*Above Median Bank Deposits / GDP*	*Below Median Bank Deposits / GDP*	*Above Median Bank Deposits / GDP*	*Below Median Bank Deposits / GDP*
Deposits/GDP X capital intensity	0.643***	0.624***	1.225***	0.263	1.235***	0.118
	(0.130)	(0.120)	(0.260)	(0.550)	(0.262)	(0.490)
Deposits/GDP	0.0129	0.081	-0.347*	0.167	-0.327	0.239
	(0.120)	(0.110)	(0.170)	(0.250)	(0.195)	(0.257)
Human Capital		0.483***	0.511*	0.156	0.465	0.143
		(0.120)	(0.250)	(0.250)	(0.323)	(0.319)
GDP per Capita		1.031***	0.736*	1.225***	0.997**	1.115***
		(0.087)	(0.360)	(0.180)	(0.435)	(0.267)
Human Capital x capital intensity					0.0981	0.0398
					(0.303)	(0.347)
GDP per capita x capital intensity					-0.439	0.191
					(0.301)	(0.348)
Technology X Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2418	2418	1221	1197	1221	1197

Potential Concern

- **Endogeneity: Technology -> Demand/Investment-> Financial development**

How we address it

- **Really differential effect of K-int tech? (No)**
- **Differential effect of income**

Invention Dates and Diffusion Lags across Technologies

	Technology	Invention Date	Median Diffusion Lags from Comin and Hobjin (2010)		Number of country-years of data within 50 years of invention	
			Full Sample	*Europe and North America*	*Full Sample*	*Europe and North America*
1	Railroad track	1825	*96*	*72*	*21*	*19*
2	Telegram	1835	*31*	*21*	*49*	*44*
3	Telephone	1875	*35*	*10*	*135*	*102*
4	Electricity Production	1882	46	20	100	74
5	Electric Arc Steel	1907	59	29	49	49
6	Blast Furnace Steel	1950	13	10	156	87
7	Cell Phones	1973	13	12	137	59
8	Ring Spindle	1779	111	78	-	-
9	Loom	1785	170	168	-	-
10	Passenger Cars	1885	36	30	118	79
11	Trucks	1885	30	26	112	73
12	Tractors	1903	57	71	-	-
13	Radio	1920	18	12	270	123
14	TV	1927	30	26	218	93
15	Personal Computers	1973	14	13	138	56
16	MRI machines	1977	5	5	59	51
	Total				1,562	909

Early vs. Late in Technology's Lifecycle

Using 50 years from invention as cutoff for "Early"

Dependent Variable is Log of Technology Diffusion per Capita

	Full Sample <50 years	*Full Sample >50 years*	*Europe & N. America <50 years*	*Europe & N. America >50 years*
Deposits/GDP X capital intensity	0.999***	-0.130	1.182***	0.401
	(0.290)	(0.390)	(0.340)	(0.250)
Deposits/GDP	-0.0767	0.437	-0.144	0.180
	(0.150)	(0.290)	(0.230)	(0.260)
Human Capital	0.104	0.022	0.802	0.419*
	(0.390)	(0.350)	(0.640)	(0.200)
GDP per Capita	1.401***	1.046***	1.017**	1.181***
	(0.290)	(0.230)	(0.400)	(0.370)
Human Capital x capital intensity	0.547	0.193	-0.153	-0.206*
	(0.480)	(0.360)	(0.630)	(0.110)
GDP per capita x capital intensity	-0.178	0.233	-0.482	0.072
	(0.340)	(0.210)	(0.350)	(0.370)
Technology X Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	1,562	3,564	909	1509

Early vs. Late in Technology's Lifecycle

Using Comin and Hobjin (2000) Diffusion Lags for Technologies

Dependent Variable is Log of Technology Diffusion per Capita

	Full Sample < Median Adoption Time	*Full Sample > Median Adoption Time*	*Europe & N. Am < Median Adoption Time*	*Europe & N. Am> Median Adoption Time*
Deposits/GDP X capital intensity	1.056***	-0.304	1.137***	0.283
	(0.270)	(0.500)	(0.320)	(0.460)
Deposits/GDP	-0.153	0.519*	-0.539**	0.493
	(0.170)	(0.260)	(0.250)	(0.340)
Human Capital	(0.120)	0.026	0.537	0.267
	(0.260)	(0.450)	(0.380)	(0.240)
GDP per Capita	1.267***	1.082***	1.695***	0.804***
	(0.420)	(0.170)	(0.480)	(0.190)
Human Capital x capital intensity	0.466	-0.0551	-0.365	0.468
	(0.340)	(0.420)	(0.390)	(0.410)
GDP per capita x capital intensity	-0.314	0.221	-0.720	0.008
	(0.300)	(0.160)	(0.420)	(0.260)
Technology X Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	2413	2713	1201	1217

Potential Concern

- Omission of var. corr with fin. development

How we address it

- Most affect symmetrically K- and non-K int tech -> captured by country FE.
- For those that do not (e.g., size), we include country FE * K int
- Also, Polity* K int
- Also, G * K int

Robustness Checks: Country x Dependence Fixed Effects

Using 50 years from invention as cutoff for "Early"

Dependent Variable is Log of Technology Diffusion per Capita

	Full Sample <50 years	*Full Sample >50 years*	*Europe & N. America <50 years*	*Europe & N. America >50 years*
Deposits/GDP X capital intensity	0.870*	-0.0664	1.017*	-0.100
	(0.467)	(0.294)	(0.500)	(0.320)
Deposits/GDP	-0.00195	0.543***	-0.0625	0.507*
	(0.261)	(0.132)	(0.245)	(0.239)
Human Capital	0.371	0.151	1.009	0.554*
	(0.409)	(0.289)	(0.685)	(0.300)
GDP per Capita	1.425***	0.894***	1.357***	1.158***
	(0.276)	(0.254)	(0.336)	(0.361)
Political Institutions	0.0172	0.0137	0.0320**	0.0208
	(0.0152)	(0.00806)	(0.0139)	(0.0132)
Human Capital x capital intensity	-0.174	-0.110	-0.757	-0.323
	(0.640)	(0.471)	(0.828)	(0.341)
GDP per capita x capital intensity	-0.351	0.174	-1.049	0.127
	-0.00791	0.000160	-0.0218	-0.0103
Political instututions x capital intensity	(0.0169)	(0.00932)	(0.0156)	(0.0148)
Technology X Year FE	Yes	Yes	Yes	Yes
Country X Capital Intensity FE	Yes	Yes	Yes	Yes
Observations	1,464	3,280	868	1,465

Robustness Checks: Country x Dependence Fixed Effects

Using Comin and Hobjin (2000) Diffusion Lags for Technologies

	Full Sample < Median Adoption Time	*Full Sample > Median Adoption Time*	*Europe & N. Am < Median Adoption Time*	*Europe & N. Am> Median Adoption Time*
Deposits/GDP X capital intensity	0.416	0.499	0.626*	-0.0446
	(0.292)	(0.287)	(0.327)	(0.434)
Deposits/GDP	0.221	0.172**	-0.267	0.699**
	(0.150)	(0.0632)	(0.244)	(0.322)
Human Capital	0.102	0.132	0.662	0.237
	(0.333)	(0.497)	(0.434)	(0.292)
GDP per Capita	1.055**	0.797***	1.427***	0.849***
	(0.465)	(0.175)	(0.415)	(0.158)
Political Institutions	0.0386***	0.00747	0.0437**	0.0258**
	(0.00823)	(0.00797)	(0.0202)	(0.0112)
Human Capital x capital intensity	0.140	-0.637	-0.602	0.283
	(0.362)	(0.692)	(0.450)	(0.386)
GDP per capita x capital intensity	-0.0603	0.392	-0.474	-0.182
	-0.0231*	0.00401	-0.0133	-0.0224
Political instututions x capital intensity	(0.0120)	(0.0110)	(0.0224)	(0.0130)
Technology X Year FE	Yes	Yes	Yes	Yes
Country X Capital Intensity FE	Yes	Yes	Yes	Yes
Observations	2,293	2,451	1,138	1,195

Robustness Checks: Government Expenditure

Dependent Variable is Log of Technology Diffusion per Capita

	Europe and North America	*Europe and North America - Post 1960*		*Europe and North America*	*Europe and North America - Post 1960*	
Deposits/GDP X capital intensity	0.711***	0.465**	0.474**	0.305	0.228*	0.265*
	(0.230)	(0.160)	(0.190)	(0.220)	(0.120)	(0.130)
Deposits/GDP	0.051	-0.093	-0.017	0.270	-0.027	0.052
	(0.160)	(0.120)	(0.130)	(0.180)	(0.110)	(0.110)
Human Capital	0.547*	-0.049	-0.045	0.635	0.073	0.095
	(0.280)	(0.180)	(0.210)	(0.360)	(0.130)	(0.130)
GDP per Capita	1.117***	0.850***	0.894***	1.512***	0.751**	0.845**
	(0.310)	(0.220)	(0.250)	(0.270)	(0.340)	(0.400)
Human Capital x capital intensity	-0.156	0.214	0.315	-0.390	-0.069	0.003
	(0.240)	(0.150)	(0.210)	(0.390)	(0.350)	(0.410)
GDP per capita x capital intensity	-0.146	0.147	0.158	-0.567	0.455	0.291
	(0.290)	(0.270)	(0.290)	(0.340)	(0.510)	(0.530)
Government Expenditure			0.032***			0.028***
			(0.008)			(0.009)
Gov Expenditure x capital intensity			-0.008			0.011
			(0.011)			(0.015)
Technology X Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Country X Capital Intensity FE	No	No	No	Yes	Yes	Yes
Observations	2418	1333	1239	2418	1333	1239

Potential Concern

- **Interpretation of classification**
- **Omission of var. corr with K-int**

How we address it

- **Trade: less capital intensive are traded**
  - Does financial development (relatively) foster trade?
  - We find the opposite
- **K-int = Human capital complementarity?**
  - Nope, we find no differential effect of human capital
- **K-int = inferior or luxury good?**
  - Nope, no diff effect of income
- **K-int = reliance on government capital?**
  - Nope

Further Robustness Checks

- **Measures of Financially Dependent technologies**
  - Placebo test of financially dependent technologies (where technologies ordered alphabetically yields insignificant results).

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Conclusions

Key findings

- Financial depth matters for technology diffusion
- But only in the early stages of diffusion in the leading countries
- No effect in later stages of diffusion or in laggard countries

Interpretation

- During the early stages of diffusion, high risks associated with uncertainty about demand, evolution of technology, its feasibility, suppliers, …
- Financial development reduces the impact of these risks on the entrepreneurs' wealth
- And induces experimentation and investments required for the technology to diffuse