Capital Market Imperfections, High-Tech Investment, and New Equity Financing*

Robert E. Carpenter

UMBC

Bruce C. Petersen

Washington University

*We thank Jamie Brown, Robert Cressy, Steven Fazzari, Stephen Machin (the editor), Dorothy Petersen, two anonymous referees, participants at the 2000 European Association for Research in Industrial Economics Conference, the University of Kent at Canterbury, and the XIII Villa Mondragone International Economic Seminar for many valuable comments and suggestions. We also thank Lauren Lax for excellent research assistance and Dorothy Petersen for technical assistance.
ABSTRACT: Highly variable returns, asymmetric information and a lack of collateral should cause small high-tech firms to have poor access to debt. New equity financing has several advantages over debt, but may be costly compared to internal finance. We examine an unbalanced panel of over 2,400 publicly traded United States high-tech companies over the period 1981 to 1998. Most small high-tech firms obtain little debt financing. New equity financing, in the form of the initial public offering, is very important and permits a major increase in firm size. After going public, comparatively few firms make heavy use of external financing.

JEL Codes: G3, O3, L6, D9

Keywords: Capital market imperfections, high-tech investment, equity financing
Standard neoclassical models of investment typically assume that capital markets are perfect. In recent years, however, a body of theoretical work has challenged the key assumptions required for perfect capital markets. If the firm has better information about its investment returns than potential investors, external finance may be expensive, if available at all, because of adverse selection and moral hazard problems. These problems are accentuated when assets have low collateral value. In addition to this theoretical work, a large number of recent empirical studies report evidence that investment for some firms appears to depend on their financial condition. There are, however, potential weaknesses in the empirical methodologies used to test for the presence of financing constraints, and some of the key evidence in the financing constraint literature has recently been challenged. The nature of the imperfections in capital markets, how to detect their presence, and how to measure their quantitative impact on firm investment remains controversial.

This paper examines how capital market imperfections may affect firms in high-tech industries. There are three reasons why high-tech investment is particularly likely to be affected by capital market imperfections. First, the returns to high-tech investment are skewed and highly uncertain, in part because R&D projects have a low probability of financial success. Second, substantial information asymmetries are likely to exist between firms and potential investors. Because high-tech investments are difficult to evaluate and frequently embody new knowledge, insiders will have much better information than outsiders about the prospects of the firm’s investments. Even if firms could educate outsiders, appropriability problems may induce firms to limit the amount of information they are willing to provide to suppliers of funds. Firms in many United States industries appear to view patents as an ineffective method of appropriating returns to R&D and often prefer secrecy (Levin, et al. 1987). Finally, high-tech investments often
have limited collateral value. R&D investment, which is predominantly salary payments, has little salvage value in the event of failure. Furthermore, physical investments designed to embody R&D results are likely to be firm specific, and therefore may have little collateral value.

Surprisingly, high-tech investment has received very little attention in the empirical literature on financing constraints. Research has not focused on particular sectors of the economy, but has instead examined such issues as the role of firm size and the importance of access to publicly traded debt. One theme of our paper is that financing constraints and funding gaps arising from imperfections in capital markets may have a much greater impact on some sectors, in particular high-tech, than in other sectors, such as retail and wholesale trade. An important reason to examine the high-tech sector is because it supplies much of the new knowledge required for economic development. If financing constraints are widespread in the high-tech sector they could potentially inhibit economic growth. Finally, the high-tech sector provides an excellent example for discussing key ideas in the literature on capital market imperfections.

The second dimension of our paper is an examination of the role new equity finance (i.e., issues of new shares) may play in partially relaxing financing constraints. We consider equity finance for several reasons. First, most of the literature on capital market imperfections has focused on debt finance, often assuming that new equity finance is prohibitively expensive or unavailable. Second, new equity has many advantages over debt for financing high-tech investment. Equity financing does not require collateral or increase the probability of financial distress, and investors’ upside returns are not bounded. Third, in recent years the use of equity finance and the number of initial public offerings appear to have risen sharply in a number of countries. Given the problems with debt financing, countries with relatively well-developed
markets for venture capital and new equity may have a comparative advantage in the production of high-tech goods.

We examine an unbalanced panel of over 2400 publicly traded United States high-tech companies over the period 1981 to 1998. Most of these firms become publicly traded firms (“go public”) during the sample period. We find that most small and medium-sized high-tech firms make little use of debt finance. For small firms, virtually all long-term debt is secured debt. New equity financing, however, plays a critical role at the time the firm makes its initial public offering (IPO). The IPO is typically very large relative to the size of the firm and it often leads to a dramatic change in the firm’s size. This increase in size could be difficult to achieve if the firm’s only source of external finance was debt. We find that most firms do not continue to make heavy use of external equity finance after they go public. Rather, the typical firm finances most of its growth with internal finance. These financing patterns suggest that many publicly traded high-tech firms, especially small firms, face financing constraints on investment and that new equity finance may be key to partially relaxing these constraints.

Policymakers in Europe have recognized the importance of promoting markets for risk capital and liquid equity markets for the development of small, high-technology companies. The United States is frequently used as a benchmark for comparison for other countries’ high-tech sectors and risk capital markets (e.g., HM Treasury, 1998, p. 13). Consequently, our results may be informative for the conduct of public policy in Europe.

The next section of the paper summarizes the reasons why the extensive use of debt finance is likely to be prohibitively costly or unavailable for firms in high-tech industries. Section 2 describes the potential advantages and disadvantages of external equity finance. Section 3 examines the financing patterns of high-tech firms and presents new empirical
evidence on the lack of debt finance and the role of new equity financing for high-tech firms. The last section briefly discusses the critical role of venture capital in bringing high-tech firms to the stage where they can conduct an IPO. We also discuss how the relative lack of venture and equity capital in Europe may impede the development of the European high-technology sector.

1. Problems With Debt

Most of the modern literature on capital market imperfections and financing constraints has ignored external equity financing, focusing instead on the firm’s access to debt. This focus is due in part to the literature’s emphasis on macroeconomic issues, particularly the role played by credit market frictions in propagating cyclical fluctuations (e.g., Greenwald and Stiglitz, 1993 and Bernanke, et al. 1998). In Hubbard’s (1998) review of the empirical literature, his discussion of financing constraints is motivated by the link between collaterizable net worth and the cost of debt. Schiantarelli’s (1995) summary of the international evidence and the empirical methodologies, particularly the modeling of debt in the Euler equation for the capital stock of the firm, also highlights the literature’s focus on debt finance.

A standard depiction of the supply of finance schedule, or the financing hierarchy, appears in Fig. 1. The flow of finance is measured on the horizontal axis, and the marginal cost of funds is measured on the vertical axis. The quantity of available internal finance is depicted by $IF$ (often proxied by cash flow) and has a constant marginal cost of $MC_{int}$. The upward sloping portion of the supply schedule represents the supply of debt finance.

There are several reasons why the extensive use of debt finance may be inappropriate for high-tech firms and why their shadow cost of debt finance may increase rapidly with greater leverage. First, the very nature of the debt contract is not well suited for high-tech investment. Creditors do not share in firms’ returns in good states of nature, and thus “lenders are only
concerned with the bottom part of the tail of the distribution of returns” (Stiglitz, 1985, p. 146). When borrowers’ returns are highly uncertain, as they are in the high-tech sector, extensive use of debt may provide negative expected returns to lenders.

Second, adverse selection problems in debt markets are likely to be most pronounced for high-tech investment. High-tech investment involves much greater uncertainty about returns than typical investments. It is also likely that firms have better knowledge than lenders about the inherent riskiness of projects. In such an environment, lenders may choose to ration credit, rather than raise interest rates, in the hopes of not exacerbating adverse selection problems (e.g., Jaffee and Russell, 1976, Stiglitz and Weiss, 1981). Credit rationing could cause the debt supply schedule to become vertical at low levels of leverage.

Third, debt financing can lead to ex post changes in behavior (moral hazard). Compared to low-tech firms, high-tech firms are likely to have substantial scope for substituting high-risk projects for low-risk projects. When creditors anticipate this behavior, they may ration credit or insist that covenants be attached to debt that restrict the firm’s behavior. Since moral hazard problems increase with the degree of leverage, the restrictions placed on the firm should become more severe as leverage increases.

Fourth, much of high-tech investment is intangible or firm specific and therefore provides little or no inside collateral value. A large body of research points to the importance of collateral for debt finance. Bester (1985, 1987) shows that collateral can be used as a signaling device to separate high-risk from low-risk borrowers and as an incentive device to confront problems of moral hazard. Boot, et al. (1991) provide a theoretical model, together with empirical evidence, showing that collateral can be a powerful instrument for dealing with moral hazard. Berger and Udell (1990) state, “Collateral plays an important role in U.S. domestic bank lending, as
evidenced by the fact that nearly 70% of all commercial and industrial loans are currently made on a secured basis.⁹ Berger and Udell (1998) summarize the empirical findings on collateral and conclude that riskier firms are more likely to pledge collateral. Empirical evidence suggests that there is a negative relationship between a firm’s leverage and its intangible assets.¹⁰ The lack of collaterizable assets held by high-tech firms should limit their access to debt financing.

Finally, the expected marginal costs of financial distress are likely to rise rapidly with greater leverage. Brealey and Myers (2000, pp. 510-523) review the many types of costs associated with financial distress, including enhanced conflict of interest problems between stockholders and lenders. They single out high-tech firms – because of their high degree of intangible and firm specific assets – as an example where the costs of distress will be important. In particular, financial distress can lead to the loss of key employees and the abandonment of critical projects. Much of the market value for young high-tech firms is based on future growth options that rapidly depreciate when firms face financial distress (Cornell and Shapiro, 1988).

Berger and Udell (this issue) emphasize “one of the most powerful technologies available to reduce information problems in small firm finance is relationship lending.” They explain that under relationship lending, “banks acquire information over time through contacts with the firm, its owner and its local community on a variety of dimensions…” They point out that small businesses tend to have long relationships with their banks. Relationship lending, however, may not work well in all sectors of the economy. In particular, young high-tech firms, because they operate in a rapidly changing environment, may have to make major investments in a time frame that is too brief to develop a close relationship with a lender. Evidence in Gompers and Lerner (1999) and Ritter (1991) shows that high-tech firms often receive external equity financing when
they are only a few years old, a period much shorter than the average length of the banking relationship reported in Berger and Udell (this issue).\textsuperscript{11}

de Meza and Webb (1987, 1990) and de Meza (this issue) present provocative models of asymmetric information in debt markets where the equilibrium outcome is characterized by overlending as opposed to the underlending that we emphasize in this paper. While their models may be insightful for some sectors of the economy, we believe that it is unlikely for the high-tech sector to be characterized by too much lending. Their models do not capture all of the reasons (e.g., financial distress) why the shadow cost of debt finance may increase rapidly with greater leverage for high-tech firms. In particular, their models do not capture the fact that inside collateral may be a critical determinant of the size of loans.\textsuperscript{12} As discussed above, the evidence indicates that when uncertainty is great, banks will likely insist that loans be secured by collateral, and inside collateral is limited for high-tech firms.

In summary, for high-tech firms, the limited collateral value of assets, together with adverse selection, moral hazard, and financial distress should cause the marginal cost of debt to increase rapidly with leverage. These factors can cause a large difference between the intersection of supply and demand under perfect capital markets and the intersection of supply and demand when the marginal cost of debt increases rapidly as depicted in Fig. 1. When debt is the only available form of external finance, there may be a pronounced funding gap, with firms investing substantially less than they would if debt were a perfect substitute for internal finance.
2. Is New Equity Financing a Solution?

Most theoretical models of financing constraints assume that financing with new share issues is impossible or prohibitively expensive. However, the rapidly growing number of publicly traded companies in many developed economies, together with the creation of equity markets in many developing nations, suggests the role of new equity financing should be given more consideration in models of imperfect capital markets. One recent effort is Bolton and Freixas (2000, p. 325) who “provide the first synthesis of capital structure choice theories and financial market equilibrium based on information and incentive considerations.” In their capital market equilibrium, the riskiest firms (e.g., start-ups) do not receive debt financing but they may obtain new equity financing.

For firms in the high-tech sector, new equity has a number of advantages over debt. Equity finance does not require the firm to post collateral, investors’ upside returns are not bounded, and additional equity financing does not increase the probability of financial distress. In addition, equity financing does not create incentives for managers to substitute towards excessively risky projects.

There are, however, capital market imperfections for new equity that can lead to a substantial wedge between the costs of internal and external equity financing. Lee, Lockhead, Ritter and Zhao (1996) report average issue costs (i.e., underwriter spreads and administrative costs) of over 13% for issues of seasoned equity of less than $10 million and costs of nearly 10% for issues between $10 and $20 million. Their estimates of issue costs for IPOs are larger still.

A second source of the wedge is the lemons premium caused by adverse selection problems arising from asymmetric information. Myers and Majluf (1984) build on Akerlof’s (1970) “markets-for-lemons” paper to explain why asymmetric information may force firms to
sell equity at a sharp discount, if they can sell it at all. Himmelberg and Petersen (1994) argue that adverse selection problems may be pronounced in high-tech industries because firms may have to actively maintain information asymmetries to appropriate returns on innovation.

Empirical evidence indicates that the lemons premium can be large. For example, Asquith and Mullins (1986, p. 85) report that the drop in the value of outstanding shares when primary new equity issues are announced average 31% of the planned proceeds of the issue. Brealey and Myers (2000, p. 423) state, “Most financial economists now interpret the stock price drop on equity issue announcements as an information effect and not a result of the additional supply.”

Fig. 2 presents a financing hierarchy modified to allow for new share issues. The diagram can apply either to firms considering an IPO or a seasoned equity offering. When the marginal cost of debt financing becomes sufficiently high, new equity financing becomes the least-cost marginal source of finance. The cost of new share issues is MC_{eqt} and the wedge between new share issues and internal equity finance is MC_{eqt} - MC_{int}, which represents the lemons premium and the issue costs associated with equity. For a number of reasons, including the fact that new share issues do not require collateral or raise the probability of financial distress, the supply schedule of new equity financing is likely to be highly elastic. The financing hierarchy depicted in Fig. 2, including the constant marginal cost of new shares issues, has appeared in previous studies, including Fazzari, et al. (1988), but little attention has been given to the implications of the new share issue portion of the supply schedule.

If the wedge in Fig. 2 is large, the marginal return on investment for most small high-tech firms will probably not be large enough to warrant the issue of new shares to outsiders. The growth of these firms should be tightly linked to available internal finance. But given the
highly skewed returns to high-tech investment, some firms with very successful R&D programs will have expected marginal returns that exceed the cost of new share issues. The investment demand schedule in Fig. 2 depicts such a case. Especially in the case of an IPO, the demand schedule should be highly elastic because small firms tend to have small market shares and can expand with relatively little impact on product price. The implication of a highly elastic supply of new equity financing, together with a highly elastic demand for financing, suggests that some firms may issue large amounts of stock relative to their current size. Given the problems with debt finance, rapid enlargement of firm size may be possible only if high-tech firms have access to external equity markets.

We now turn to an examination of the financing patterns of high-tech firms. The arguments in section 1 suggest that small, high-tech firms should use little debt both prior to and after going public. The arguments in section 2 (summarized by Fig. 2) indicate that the size of the IPO may be very large relative to the size of the firm. We examine both the absolute and relative magnitudes of the IPO. We also consider the role of internal versus external equity financing after the IPO. If new equity issues after the IPO send strong negative signals to investors, it may cause firms to rely predominantly on internal equity financing after they go public.19

3. The Financing of High-Tech Firms

The Data and Sample of Firms

We use Compustat, including its research file, to construct the sample. To permit identification of changes in financial patterns over time, we divide the sample period into three six-year sub-periods: 1981-1986, 1987-1992, and 1993-1998. We select the set of high-
technology industries based on the United States Department of Commerce classification of high technology. The list of industries in the sample consists of: drugs and medicinals (SIC 283), office and computing equipment (SIC 357), communications equipment (SIC 366), electronics components (SIC 367), industrial measuring instruments (SIC 382) and surgical instruments (SIC 384). All of these industries are very R&D intensive, particularly when they are compared to the rest of the United States manufacturing sector.

One advantage of our data is that we have not only data for existing publicly traded companies, but also financial information for firms just before they go public. Standard and Poor’s, which maintains the data, informed us that Compustat typically contains one or two years of data (from the company’s prospectus) prior to the year in which the firm goes public. Standard and Poor’s also informed us that the first incidence of a non-missing stock price indicates the year in which the firm goes public.

Table 1 reports the number of firms that are already public at the beginning of our sample period as well as the number of firms that go public over each of the three sub periods of the data. The first column of Table 1 indicates that the data contain 630 publicly traded firms at the beginning of 1981. Drug and medicinals has the fewest number of firms (72) and office and computing equipment has the largest (127). The next three columns report the number of new public firms, by period, in each of the six high-tech industries. There are 605 new public firms in the first period, 500 in the second, and 703 in the last period. The industry with the largest number of new public firms is computing equipment in the first period, surgical instruments in the second period, and drugs and medicinals in the last period.

*The Absolute and Relative Size of the IPO*
Table 2 reports information on the size of firms and the absolute and relative magnitude of equity issues for the year that the firm goes public. To economize on space, we have not reported the results for individual industries. We report information at both the median and the 90th percentiles of the distribution. Most firms are small at the time they go public. The median firm had 89 employees in the first period, 70 in the second, and 75 in the last period. Employment at the 90th percentile is close to 500 employees in each of the periods. In terms of total assets, which consist primarily of physical and working capital, but not R&D investment, the median firm had slightly more than $5 million in the first two periods and approximately $9 million in the last period. Overall, the size distribution of firms is similar across the three time periods. Total assets are commonly used as a measure of firm size, and we use it as the scale factor in subsequent tables.

Rows three and four show the firms’ use of debt finance in the year of the IPO. Row three shows the beginning-of-year stock of long-term debt scaled by total assets. The median debt-asset ratio is 0.080 in the first period and 0.050 in the next two periods, indicating low debt use just prior to the IPO. Row four shows the flow of debt finance in the year of the IPO. The median firm retires a small amount of debt while firms at the 90th percentile have positive debt flows. The small debt stocks are consistent with the theoretical prediction that high-tech firms do not use debt finance extensively. As we now show, the stock and flow of debt ratios are very small when compared to the new equity raised by firms in the year of the IPO.

Rows five and six provide information on the absolute and relative size of new equity issues. Median new equity issues (in 1992 dollars) have risen from $5.27 million in the first period to $17.67 million in the last period. At the 90th percentile, the figures are much larger, ranging from $31.51 million to $51.36 million. Median values of new equity issues relative to
beginning of year assets is 1.36 in the first period and 2.10 in the last period. At the 90th percentile, they range from 7.86 in the first period to 12.38 in the last period. The results show the importance of the IPO for increasing the size of the firm. The median new public firm doubles, or even triples, its assets. Firms in the tail of the distribution increase their asset size by ten-fold or more with their IPO. Over time, there has been a sharp rise in both the absolute and the relative size of the IPO.

Table 3 reports information on the absolute and relative size of equity issues by new public firms in the year of the IPO and for the five years following it. Reading across the top of the table, the year the firm goes public is denoted $t+0$. Rows one and two report the median value of new equity issues and the size of the issue scaled by the firm’s beginning of year assets. In the year of the IPO, median new equity, combining the data for all three sub-periods of the sample, is approximately $10 million and the median ratio of new equity to total assets is 1.76. In year $t+1$, new equity financing plummets, falling to $0.29 million. The equity finance-total asset ratio falls to 0.011. The median values for both statistics in years $t+2$ through $t+5$ are only slightly larger than those for $t+1$.

Rows three and four report the absolute and relative size of equity issues at the 90th percentile. In the year of the IPO, the value of the equity issue is $44.45 million, and the relative size of the issue is 10.48. Like the medians, the value of equity issues at the 90th percentile, as well as the relative size of the issue, drops off sharply in year $t+1$. Funds raised by issuing new shares fall to $15.60 million and size of the equity issue relative to the firm’s total assets is 0.89. The values in $t+2$ to $t+5$ are similar to those in $t+1$. The results in Table 3 indicate that after the IPO, equity issues drop off dramatically for most firms. Some firms, however, continue to use equity after the IPO in quantities large enough to substantially increase their size.
We also computed the size of the median firm for the years immediately following the IPO. Firms experience a very sharp increase in size. At $t+0$, the median firm has assets of $6.9 million and 85 employees. By $t+5$, the median firm has assets of $23.37 million and 144 employees, or more than a three fold increase in assets and a 70% increase in employees. The IPO appears to bring about a very large increase in firm size.

*After the IPO: The Financing Behavior of Established Firms*

Table 4 reports information on the sources and uses of finance for established firms. Established firms are defined as those who have been publicly traded for at least two years. Thus, two years after going public, the firms examined in Table 2 are allowed to enter the data used to construct Table 4. Because the literature on financing constraints has argued that small firms are more likely to face substantial financing constraints, we break the established firms into three size classes. Small firms are defined as those with asset sizes between $1 and $50 million; medium firms have assets between $50 and $250 million; and large firms have assets greater than $250 million. For each of these three size categories, we calculated the financial statistics for each of the three sub-periods reported in Tables 2 and 3. With only a few exceptions noted below, the results are stable over time. Therefore, to simplify the presentation, we report Table 4 for the entire sample period. Because the sample period spans 18 years, we allow firms to move between size categories.

To construct the results in Table 4, we calculate the financial ratios for each year for each firm. We use beginning-of-year assets as the scale factor. For each size category, we use the firm’s average (while it is in a size category) as a data point when we compute the distribution of the ratios. An alternative approach would be to use each observation for each firm as a data point. This approach, however, would understate the importance of external finance if it is
“lumpy” because of fixed issue costs. We report the median and 90th percentile of each variable. Rows two through four report information on uses of finance while rows five through ten provide information on sources of finance.

The ratio of physical investment to assets and the ratio of R&D expenditures to assets are listed in rows two and three. The median values for the physical investment ratio range from 0.05 for small firms to 0.08 for large firms. The median values for the R&D ratio are large, and range from 0.11 for small firms to 0.09 for large firms. At the 90th percentile, R&D expenditures are extremely high, especially for small firms. These results indicate that for many high-tech firms, R&D investment is often much greater than physical investment. The results also underscore the fact that a large fraction of a high-tech firm’s investment is intangible, particularly for small firms. Row four reports the ratio of dividends to assets. The median value is zero for all size classes. Even at the 90th percentile, dividend payouts are small, indicating that most firms retain essentially all of their internal funds, as would be expected if there are financing constraints.

The remainder of Table 4 reports information on the firms’ sources of finance. Following Hall (1992) and Himmelberg and Petersen (1994), we define gross cash flow as cash flow plus R&D expenses. We add R&D back to cash flow because R&D is treated as an expense for accounting purposes, not as an investment. Gross cash flow scaled by assets provides a measure of the internal finance of the firm available for total investment, including R&D. Since we wish to compare the size of cash flow relative to investment, we also construct the ratio of gross cash flow, net of physical investment and R&D, to total assets.

In row five, the median value of the gross cash flow to asset ratio ranges from 0.20 for small firms to 0.31 for large firms. The gross cash flow to asset ratio exceeds the sum of the median values of the investment to asset ratio plus the R&D to asset ratio at both the median and
the 90th percentile. Row six, which reports gross cash flow net of physical investment and R&D, divided by assets, confirms this fact. At the median, this ratio is 0.03 for small firms and it is larger for the other two size classes. Since the sample firms do not typically pay dividends, one may wonder where the residual cash flow is going. Part of the residual cash flow is used for working capital investment, which includes inventories and accounts receivable (see Fazzari and Petersen, 1993 and Carpenter, et al. 1994). In addition, firms can also use cash flow to acquire the assets of other firms, a use of funds excluded from Compustat’s measure of physical investment.

Row seven reports that the ratio of the median flow of new long-term debt relative to assets is zero, or close to zero, in all size classes. At the 90th percentile, the use of debt is modest, and it is only about 50% of the size of median gross cash flow. Row eight reports the ratio of the stock of long-term debt to assets. For small and medium firms, the median value is 0.08, similar to the value reported in Table 2 for firms at the time of the IPO. The median value is 0.15 for large firms. These debt-stock ratios are small, particularly when one considers that the stock of assets in the denominator of the ratio does not include R&D investment.23

Row nine reports the ratio of secured debt to total long-term debt. Presumably, even high-tech firms have some assets (e.g., buildings) that can be pledged as security for loans. For small firms the median value of the ratio is near one. For medium firms the median is 0.70. These high ratios suggest that most loans must be secured, consistent with the evidence in Berger and Udell (1990) and Berger and Udell (this issue). These ratios, together with the limited collateral value of high-tech investment, help to explain firms’ low use of debt (indicated in rows seven and eight). In contrast, for large firms the ratio of secured debt to total long-term debt is only 0.131.
The sharp drop and low value of this ratio suggests that the problems associated with debt finance for high-tech investment is much smaller for large, established firms.

The final row shows that the median value of the flow of equity financing to assets is small for all size classes, ranging from 0.05 for small firms to 0.01 for large firms. Even for small firms, external equity financing is only approximately 25% the size of gross cash flow. At the 90th percentile, however, the ratio of equity financing to assets is 0.62 for small firms and 0.39 for medium firms. These ratios are sizable, especially for small firms, where the 90th percentile of equity financing is larger than the 90th percentile of gross cash flow. While the use of new equity by existing firms is nowhere near as large as equity issues at the time of the IPO (see the last row in Table 2), Table 4 suggests that some small firms do obtain large amounts of follow-up equity financing.24

In contrast to our results, Berger and Udell (this issue) report that debt constitutes approximately 50% of total financing for the sample of small firms discussed in their study. Their sample (and an identical sample they use in their 1998 paper) comes from the 1993 National Survey of Small Business Finances. The majority of the firms (68.4%) are in business services, professional services, retail trade, and wholesale trade. Only a very small proportion of the surveyed firms are in the high-technology sector.25 In general, information problems in service industries and in retail and wholesale trade are likely to be much less important than they are in the high-tech sector. In addition, assets in these sectors are likely to have substantially higher collateral values than the assets of a high-tech firm. The importance of collateral for small firms is apparent from the results presented by Berger and Udell (1998, Table 2, Section D), who report that approximately 90% of debt is secured, similar to our findings in Table 4. Thus, a likely explanation for the low debt figures in our sample compared with Berger and Udell’s is
that the composition of the two samples is very different, and that high-tech firms have relatively little collateral to secure their loans.

4. Conclusions and Implications

Because of asymmetric information problems and a lack of collateral, many high-tech firms, especially small firms, are likely to face financing constraints. Adverse selection and moral hazard problems, together with financial distress, suggest that the marginal cost of debt finance may rise rapidly and potentially lead to large funding gaps. For high-tech firms, new equity finance has several potential advantages over debt finance. In our panel of over 2400 United States high-tech firms, we find that most small firms obtain little debt financing. The IPO, however, is typically very large relative to the existing assets of the firm and it often leads to a dramatic change in the firm’s size. After going public, new equity financing remains important for some firms, but most firms appear to obtain the bulk of their financing from retained earnings. Overall, new equity finance appears to be very important to the rapid growth of young high-technology firms.

The issues addressed in our research have several implications for public policy. It is likely that firms in many countries conduct too little investment in the high-tech sector compared to a benchmark model with perfect capital markets. Given the problems of debt finance outlined in section 1, together with our findings on its limited use, overlending (e.g., de Meza, this issue) is unlikely to be present in the high-tech sector. de Meza (this issue) also discusses the possibility that asymmetric information can lead to too much equity financing. Even developed countries, however, often do not have well-developed markets for external equity finance. When there are relatively few publicly traded companies, it seems unlikely that there are socially excessive levels of external equity financing.
Venture capital is the form of equity financing that is currently best suited to address the capital market imperfections inherent in the financing of young high-tech companies. Venture capitalists typically monitor the firms they fund closely and have effective tools to partially overcome information and agency problems. In the United States, the majority of venture capital is invested in the high-tech sector, where monitoring and information evaluation are important (Gompers and Lerner, 1999, Table 7.2). One role of venture capitalists is to provide start-up funding for new firms. Should a new firm reach a stage where it requires large amounts of funding, a second role of venture capitalists is to use their reputation to provide some assurance to public investors about the quality of the firm and the value of the IPO (Megginson and Weiss, 1991). Given our findings on the relative size of IPOs, the certification role played by venture capitalists is likely to be important.

There are a wide range of public policies that may improve high-tech firms’ access to equity financing, including venture capital. Lerner (this issue) examines public venture capital programs as a public policy response to the financing problems faced by SMEs. Jeng and Wells (2000) examine the determinants of venture capital funding in 21 countries. Their review of public policy in such countries as the United States, the United Kingdom, Portugal, Norway, and Israel indicates that the institutional and legal environment, including tax policy, can play an important role in encouraging the expansion of equity finance. For some countries, such as Portugal and Norway, they report that government funding of venture capital has been associated with large increases in the flow of private funds into venture capital (p. 278).

Governments can also actively encourage the development of stock markets for small high-tech companies, including the reduction of regulatory barriers to listing. In the US, low barriers to listing on the NASDAQ and the NASDAQ Small Cap enhance the ability of a young
high-tech firm to obtain new equity finance. The regional system of exchanges that form the recently developed Euro NM, as well as the EASDAQ and the AIM in the United Kingdom, are all examples of markets that are similar to NASDAQ in terms of their relatively low barriers to listing. These markets should aid in the development of the European high-tech sector.

Financial obstacles to entrepreneurship and to the growth of the high-tech sector have been the focus of much public policy discussion in Europe and have been identified as potential weaknesses of the European Union (Bank of England, 1996; European Commission, 1998, 1999b). There is concern that a lack of venture capital (private equity) may be an important barrier to the development of the European high-tech sector. While venture capital in Europe has grown rapidly in the past few years, it is significantly smaller than in the US. Venture capital in the United States is also concentrated in the high-tech sector to a much larger degree than it is in Europe, and United States venture capitalists focus more intensively on early-stage investments. There is also continued concern that small high-technology firms in Europe have more difficulty than their United States counterparts in gaining access to public equity capital. In 1997, for example, small firms raised more than 7 times the amount of capital on the Nasdaq as was raised on the Easdaq, Euro.NM, and AIM, combined (European Commission, 1998).

To promote the growth of small high-tech firms, we believe that European policymakers have correctly emphasized the development of markets for public equity finance and private venture capital. Debt is likely to be a poor substitute for equity. High-tech firms unable to obtain equity financing may face substantial financial barriers to entry and mobility. Our results suggest that institutional factors that affect the availability and cost of equity financing may be an important determinant of the comparative advantage of nations in the production of high-tech goods.
References


2 A criticism of some studies is that investment demand is difficult to measure with precision and cash flow, a proxy for access to internal finance, may be positively correlated with demand. Kaplan and Zingales (1997) challenge much of the empirical financing constraint literature. Fazzari, et al. (2000) dispute most of Kaplan and Zingales’s criticisms.

3 Mansfield et. al. (1977) reports a probability of financial success for R&D projects of only 27%. Harhoff, et al. (1999) report evidence on the high degree of skewness of the returns of German patents.

4 Cornell and Shapiro (1988, p. 14) provide a succinct statement of the problem: “The credibility gap between management and investors is likely to be most pronounced in the case of growth companies because management in such cases will often have far better information about future profitability of undeveloped products and untapped niches. This greater possibility for important information increases the amount by which investors will discount the price of new corporate securities to compensate for information disadvantages.”

5 One exception is Himmelberg and Petersen (1994), who examine R&D investment for a comparatively small set of firms in the high-tech sector. They find evidence of financing constraints for both R&D and physical investment. See also Harhoff (1998).

6 Some examples include Gilchrist and Himmelberg (1995), who consider both size and access to public debt, and Calomiris, et al. (1995). Carpenter, et al. (1994) use firm size as proxy for access to external finance and examine whether inventory cycles can be explained by fluctuations in internal finance.
See, for example, the diagram in Bernanke, et al. (1998) and Hubbard (1998).

Berger and Udell (1998, pp 639-642) provide an overview of the literature on inside and outside collateral. Outside collateral involves assets outside of the firm (e.g., the owner’s personal assets). While outside collateral is important for very small firms, inside collateral is presumably the critical form of collateral for firms of some size (e.g., corporations with multiple shareholders). Berger and Udell (1998) note that the practitioner literature has focused on inside collateral and usually predicts that lenders will more often require riskier borrowers to secure their loans.

Cressy and Toivanen (1998) provide similar evidence on the proportion of loans that are collateralized in Europe.

See Gompers and Lerner (1999, pp. 143-144) for a brief review of the literature.

Berger and Udell (this issue, Table 2) report that the average length of the relationship between their sample firms and their banks is 9.37 years, indicating a lengthy relationship. In contrast, Gompers and Lerner (1999, Table 7.4) indicate that the first private equity financing typically occurs when firms are only a few years old. Ritter (1991) presents evidence that shows the high-tech firms in his sample go public when they are very young. (In the industries that correspond approximately to those in our sample, the weighted average of the firms’ age at the IPO was 5.4 years).

In de Meza and Webb (1987), entrepreneurs invest their personal wealth in the project. de Meza (this issue) refers to the personal wealth as collateral. The entrepreneur’s wealth, however, is not part of the bank’s return in the event of bankruptcy. That is, the loan is not secured in the sense that, in the event of bankruptcy, inside or outside assets go to the bank.
13 The reviews of the literature by Hubbard (1998) and Schiantarelli (1995) indicate that little attention has been given to new equity financing. Most studies do not mention new equity as a possible source of finance. Many studies (e.g., Greenwald and Stigliz, 1993, p. 79) explicitly assume that external equity financing is prohibitively expensive.

14 As discussed in Jensen and Meckling (1976), issuing external equity may have agency costs. When the owner-manager owns a smaller fraction of the firm, there may be a reduction in effort. We note, however, that for young start-up firms, owner-managers typically have most of their wealth and compensation tied up in the fate of the firm. This suggests that owner-managers will have very powerful incentives to put forth maximum effort.

15 Jenkinson (1990) provides a comparison of the regulations governing the IPO process in the United States and United Kingdom. He reports slightly smaller direct costs of making an IPO in the United Kingdom, but like the US, direct costs are larger for smaller issues.

16 This evidence is consistent with Loughran and Ritter (1997), who find that firms appear to take advantage of information asymmetries in their choice of the timing of new share issues. There is also a substantial body of evidence supporting a lemons premium for IPOs. See, for example, the review of the literature in Gompers and Lerner (1999, chapter 10).

17 An important exception is Bond and Meghir (1994) who modify the firm’s Euler equation to allow for a hierarchy of finance, including new share issues. Carpenter and Petersen (2000) show that small firms that obtain substantial quantities of new equity financing have only a weak relationship between growth and internal finance, consistent with the financing hierarchy in Fig. 2.

18 Because the firms in our sample are either publicly traded or become publicly traded during the sample period the firms’ owners are clearly willing to trade a portion of control rights for
financial resources. Therefore "supply side financing constraints" rather than "demand side financing constraints" (as these terms are defined by Cressy and Olofsson, 1997) are more likely to affect the firms in our sample. Demand side financing constraints are internal to the firm, and arise, for example, when managers wish to avoid relinquishing control of the firm by issuing equity or by borrowing (see the model in Cressy, 1995).

19 In the model developed by Myers and Majluf (1984), the size of assets in place is critical to the size of the lemons premium and whether good firms choose to issue stock. For start-up companies, assets in place are typically very small. After the IPO, however, assets in place are larger, and therefore asymmetric information may cause more serious adverse selection problems in the market for follow-up equity issues.

20 United States Department of Commerce, “An Assessment of United States Competitiveness in High-Technology Industries” February 1983. We exclude industries from the Department of Commerce’s list that have only a small number of firms (SIC 361, 362, 386, and 387). We also exclude the aerospace industries because the United States government supplies much of the financing for R&D.

21 In approximately 85% of the sample firms, Compustat reports information for a new firm one or two years prior to it becoming a public firm. We checked the company histories of a large fraction of the new firms to determine if the initial public offering occurs in the year the stock price appears. We found no exceptions. We excluded a small number of new firms with missing values for new equity from the sample.

22 The results are similar for other points in the distribution. In all years after the IPO, equity issues at the 10th percentile are zero and are very small at the 25th percentile. At the 75th
percentile, for t=0 through t+5, issue sizes are: $24.78, $2.50, $3.64, $3.65, $4.19 and $3.43. The corresponding relative issue sizes are: 4.34, 0.190, 0.285, 0.234, 0.187 and 0.113.

23 The ratio of the stock of total debt (which includes short term liabilities such as accounts payable in addition to long term debt) to assets was also small. It was 0.16, 0.12, and 0.18 for small, medium, and large firms at their respective medians. The median flow of total debt, scaled by assets, was 0, 0.002, and 0.02 for small, medium, and large firms, respectively.

24 We examined the new equity figures by time period (as defined in the text). There is a sharp trend in the data, with much larger figures for new equity financing in the most recent time period. This is consistent with the sharp increase over time in the size of IPOs reported in Table 2.

25 Source: 1993 National Survey of Small Business Finances: Public Use Data Base Frequency Distributions (May 26, 1999). The National Survey of Small Business Finances contains information about the two-digit SIC classification of sample firms. Only 3.2% of the firms in the survey are in the four, two-digit SIC categories that contain the three-digit SIC categories that we use to define high-tech firms. Therefore, the number of high-tech firms in the sample must be less than 3.2% of the total, and is probably substantially so.

26 Gompers and Lerner (2000) review the literature and provide new evidence that venture-backed firms outperform nonventure IPOs.

27 For example, European venture capital investment totaled 7 billion Euros in 1998 compared to 12 billion Euros in the United States. (European Commission, 1999b, page 4).

28 Over 80% of United States venture capital investments are directed toward information technology, biotechnology, and healthcare. These sectors account for less than 28% of European private equity investment (European Commission, 1999a). Only 1.6 billion Euros were invested
in early stage financing in the European Union in 1998, compared to 4.5 billion Euros in the United States. Early stage venture capital investment in the United Kingdom, one of Europe’s leading sources for venture capital, was only 6% as large as in the United States in 1997 (HM Treasury, 1998). And although early stage investments are growing rapidly, the largest portion of venture capital investment in Europe is still devoted toward later stage investments, and in particular, management buyouts and buy-ins. For evidence on composition of United Kingdom venture capital investments see the Bank of England (2000, page 39) and for Europe see the European Commission (2000, pages 4 and 5).
Fig. 1. *Supply of Finance with Debt*
Marginal Cost and Returns

\[ MC_{eqt} \]

\[ MC_{int} \]

Fig. 2. Supply of Finance with Debt and New Equity
Table 1
Sample Composition: Number of Existing and New Public Firms

<table>
<thead>
<tr>
<th>Industry</th>
<th>Existing Firms</th>
<th>New Public Firms</th>
<th>New Public Firms</th>
<th>New Public Firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Drugs &amp; Medicinals</td>
<td>72</td>
<td>103</td>
<td>131</td>
<td>204</td>
</tr>
<tr>
<td>2. Office &amp; Computing Equipment</td>
<td>127</td>
<td>145</td>
<td>94</td>
<td>130</td>
</tr>
<tr>
<td>3. Communications Equipment</td>
<td>93</td>
<td>94</td>
<td>47</td>
<td>92</td>
</tr>
<tr>
<td>4. Electronics Components</td>
<td>118</td>
<td>68</td>
<td>50</td>
<td>92</td>
</tr>
<tr>
<td>5. Industrial Measuring Instruments</td>
<td>129</td>
<td>77</td>
<td>44</td>
<td>68</td>
</tr>
<tr>
<td>6. Surgical Instruments</td>
<td>91</td>
<td>118</td>
<td>134</td>
<td>117</td>
</tr>
<tr>
<td>7. Column Total</td>
<td>630</td>
<td>605</td>
<td>500</td>
<td>703</td>
</tr>
</tbody>
</table>

Existing firms, reported in the first column, are firms that are publicly traded at the beginning of 1981. The next three columns report the number of firms going public, as indicated by the presence of a stock price, in the periods 1981-1986, 1987-1992 and 1993-1998, respectively.
Table 2
Use of Debt and Equity for Firms in the Year of their IPO

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50th</td>
<td>90th</td>
<td>50th</td>
<td>90th</td>
<td>50th</td>
<td>90th</td>
</tr>
<tr>
<td></td>
<td>percentile</td>
<td>percentile</td>
<td>percentile</td>
<td>percentile</td>
<td>percentile</td>
<td>percentile</td>
</tr>
<tr>
<td>1. Employment</td>
<td>89</td>
<td>468</td>
<td>70</td>
<td>500</td>
<td>75</td>
<td>483</td>
</tr>
<tr>
<td>2. Total Assets (millions of $)</td>
<td>5.22</td>
<td>30.92</td>
<td>5.25</td>
<td>39.26</td>
<td>9.14</td>
<td>40.56</td>
</tr>
<tr>
<td>3. Ratio of Long-Term Debt to Total Assets</td>
<td>0.08</td>
<td>0.41</td>
<td>0.05</td>
<td>0.50</td>
<td>0.05</td>
<td>0.50</td>
</tr>
<tr>
<td>4. Ratio of New Long-Term Debt to Total Assets (flow)</td>
<td>-0.002</td>
<td>0.22</td>
<td>-0.004</td>
<td>0.18</td>
<td>-0.01</td>
<td>0.10</td>
</tr>
<tr>
<td>5. New Equity Issues (Millions of $)</td>
<td>5.27</td>
<td>31.51</td>
<td>8.99</td>
<td>44.29</td>
<td>17.67</td>
<td>51.36</td>
</tr>
<tr>
<td>6. Ratio of New Equity to Total Assets</td>
<td>1.36</td>
<td>7.86</td>
<td>1.73</td>
<td>10.31</td>
<td>2.10</td>
<td>12.38</td>
</tr>
</tbody>
</table>

Dollar figures are expressed in real terms (1992=100). Total assets and the ratio of long-term debt to total assets (stock) are calculated using their beginning of year values. The ratios of new long-term debt and new equity to total assets also use the beginning of year asset value.
<table>
<thead>
<tr>
<th>Table 3</th>
<th>Use of Equity by New Public Firms: Post-IPO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
</tr>
<tr>
<td>1.</td>
<td>New Equity Issues (Millions of $)</td>
</tr>
<tr>
<td>2.</td>
<td>Ratio of New Equity to Total Assets</td>
</tr>
<tr>
<td></td>
<td>90th Percentile</td>
</tr>
<tr>
<td>3.</td>
<td>New Equity Issues (Millions of $)</td>
</tr>
<tr>
<td>4.</td>
<td>Ratio of New Equity to Total Assets</td>
</tr>
</tbody>
</table>

The year of the IPO has the time index \( t+0 \). Dollar figures are expressed in real terms (1992=100).
### Table 4
Sources and Uses of Funds: Established Firms

<table>
<thead>
<tr>
<th></th>
<th>Small Firms</th>
<th>Medium Firms</th>
<th>Large Firms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50th percentile</td>
<td>90th percentile</td>
<td>50th percentile</td>
</tr>
<tr>
<td>1. Number of Firms</td>
<td>1030</td>
<td>582</td>
<td>268</td>
</tr>
<tr>
<td>2. Ratio of Investment to Total Assets</td>
<td>0.05</td>
<td>0.12</td>
<td>0.07</td>
</tr>
<tr>
<td>3. Ratio of R&amp;D Spending to Total Assets</td>
<td>0.11</td>
<td>0.39</td>
<td>0.11</td>
</tr>
<tr>
<td>4. Ratio of Dividends to Total Assets</td>
<td>0.00</td>
<td>0.02</td>
<td>0.00</td>
</tr>
<tr>
<td>5. Ratio of Gross Cash Flow to Total Assets</td>
<td>0.20</td>
<td>0.51</td>
<td>0.30</td>
</tr>
<tr>
<td>6. Ratio of (Gross Cash Flow - Investment - R&amp;D) to Total Assets</td>
<td>0.03</td>
<td>0.21</td>
<td>0.10</td>
</tr>
<tr>
<td>7. Ratio of New Long-Term Debt to Total Assets (flow)</td>
<td>0.00</td>
<td>0.09</td>
<td>0.00</td>
</tr>
<tr>
<td>8. Ratio of Long-Term Debt to Total Assets (stock)</td>
<td>0.08</td>
<td>0.32</td>
<td>0.08</td>
</tr>
<tr>
<td>9. Ratio of Secured Debt to Total Long-Term Debt</td>
<td>0.96</td>
<td>1.22</td>
<td>0.70</td>
</tr>
<tr>
<td>10. Ratio of Equity Finance to Total Assets</td>
<td>0.05</td>
<td>0.62</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Established firms are defined as those who have been publicly traded for at least two years. Small firms are defined as those with asset sizes between $1 and $50 million; medium firms have assets between $50 and $250 million; and large firms have assets greater than $250 million. Gross cash flow (row 5) is defined as cash flow plus research and development expenses.