Economic White Paper on National Third Generation Wireless Standards

*Joseph Farrell and Michael D. Topper**

I. Summary

Third generation (or 3G) is the term given to the next major advancement in wireless communications. Third generation is expected to encompass a wide range of new and enhanced wireless services such as high-speed data transmission, desktop computing in a mobile enviroment, Internet access, and video on demand.

Standards bodies around the world are currently reviewing third generation options for the radio interface between wireless handsets and base station transceivers. There are three different and incompatible second generation digital standards in use in the U.S.: TDMA IS-136, GSM, and CDMA IS-95, and proponents of each of these standards are developing their own versions of third generation technology. In addition, Nextel Communications competes with cellular and PCS operators using a fourth standard, the integral Digital Enhanced Network (iDEN) technology developed by Motorola.

We have been asked to study whether the U.S. government should mandate a national standard for third generation wireless telecommunications. Government should only mandate

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* Joseph Farrell is Professor of Economics at the University of California, Berkeley, and was Chief Economist at the Federal Communications Commission (FCC) from January 1996 to June 1997. Michael Topper is Senior Manager at Cornerstone Research and Lecturer in the Department of Economics at Stanford University.

a standard when there is clear and convincing evidence that the market will fail to achieve economically efficient results and that this market failure will be worse than the likely inefficiencies of government-mandated standards. In the case of third generation wireless standards, on the contrary, there is much evidence that market competition among multiple third generation standards will better achieve the efficiency goals that a national standard might be thought to confer.[1] Standards policy should be set on that efficiency basis, reflecting public interests.

There are four main reasons supporting our conclusion. First, in many important respects, economic efficiency is harmed if government *mandates* a single standard rather than allowing multiple standards to compete in the marketplace. Allowing multiple third generation standards to compete can create greater product variety and reduce incremental buildout costs. Moreover, it can create stronger incentives for innovation, allow the market to resolve uncertainty regarding the relative performance of competing standards, and reduce the need for regulatory or consensus management of the industry.[2]

Second, we understand that proponents of a mandated standard point to economies of scale in production and seamless nationwide roaming as putative benefits of a single U.S. standard. However, examination of the U.S. wireless service market and of the

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[1] Recent proposals that the government should force the convergence of W-CDMA and cdma2000 would preserve a limited amount of market competition, since the converged standard would compete against the third generation TDMA standard. However, the benefits of multiple standards described in this paper are best achieved by allowing all three standards to compete in the marketplace.

[2] A*llowing* multiple standards need not stop the emergence of a single US standard through market forces or private standard setting bodies. In other words, *mandating* a single standard is not necessarily required in order to achieve any benefits associated with *having* a single US standard (although we believe that the latter benefits are quite limited in this case). A single standard that emerges from market forces or consensus

wireless manufacturing market indicates that economies of scale and efficient nationwide roaming in third generation wireless are likely to come about even absent a single U.S. standard. Thus, there is no need for a single national standard, let alone for a government mandate with its attendant harms.

Third, we understand that some interested parties point to the alleged prospect of job creation as a reason to mandate a standard. But the primary consideration of a standards policy should be economic efficiency and the long-run interests of consumers — not the special interests of specific manufacturers and associated claims about jobs. The wireless manufacturing industry is only a fairly small part of the picture. U.S. consumers, U.S. service providers, and the federal budget all benefit when the market is allowed to choose the best mix of technologies.

Fourth, even taking the "jobs" argument on its own terms, manufacturing jobs and manufacturing leadership depend very much on a host of factors that affect manufacturing advantages, not simply on the country of origin of a standard. It would therefore be a leap of faith to assume that a U.S.-mandated third generation standard would lead to lasting benefits for U.S. manufacturers or manufacturing workers. The evidence is that wireless manufacturing jobs are internationally mobile.

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voluntary standard-setting is likely to be less damaging to innovation and competition than a compulsory government mandate.

II. Benefits of Multiple Standards

There are many important benefits of multiple standards that are sacrificed if government mandates a single standard rather than allowing multiple standards to compete in the marketplace. As we discuss below, these benefits include: (a) greater product variety, both on the consumer side and also helping network operators minimize costs; (b) additional incentives for innovation because of inter-technology competition; (c) avoiding locking in an obsolete technology; and (d) less need for government or broad consensus regulation of technology, with all the thorny problems such regulation creates.

A. Variety

Because any single standard, by definition, constrains design to some extent, multiple standards increase the variety of products available to firms and consumers relative to a single mandated standard. This increase in variety arises because multiple standards provide firms with more freedom and flexibility in product design choices, and provide consumers with more choices.

In general terms, there can be a trade-off between potential benefits of compatibility and the benefits of greater variety. This tradeoff is broadly similar to the tradeoff between production-side scale economies and variety. Mandating a single standard in order to ensure compatibility, without very careful examination of the costs and benefits, is like mandating that the only automobiles be black Model-T Fords in order to ensure production economies

of scale. While it might be cheaper to produce only black Model-T Fords, customers were willing and are willing to pay the additional costs for a variety of makes and colors.

Because of the benefits of variety, we do not and should not normally mandate compliance with a single product design in order to obtain economies of scale: in general, there is no reason to expect the market to yield predictably too much variety and too little economies of scale.[3] Although the ways in which the market internalizes coordination benefits are complex, as discussed below, we should also be very cautious in intervening in the tradeoff between variety and any benefits of a single standard.

As a corrective to hasty inclinations to mandate a standard so as to achieve coordination benefits, consider the personal computer market. The "IBM/Wintel" standard has long had a greater variety of mass-market applications programs, and often lower hardware prices, than other personal-computer platforms, including the Apple standard. A significant number of users nevertheless prefer the latter, perhaps because of its closer integration, or because (at least originally) it may have offered better abilities in graphics applications. Other users prefer Unix-based systems. Imagine how different the computer market would be if the government had mandated a single standard. Mandating a single standard for computing would sacrifice all these gains from product variety.[4]

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[3] Indeed, just as with large economies of scale, it is quite possible that the market may tend to *over*-realize economies of coordination and *under*-provide variety and continuing inter-standard competition.

[4] In addition, it would raise severe competitive issues. Mandating adherence to Wintel is not on most people's lists of "what to do about Microsoft/Intel." As we discuss below, mandating a standard for third generation wireless would also raise competitive problems.

In the case of second generation wireless telecommunications, the openness to multiple standards has led to product variety that has benefited consumers. Consumers have benefited directly from the variety of features available. Consumers have also benefited through the variety of network buildout options available to service providers, which results in greater service availability and lower prices.

An example of feature variety is provided by Nextel. Competing in the wireless market with Enhanced Special Mobile Radio (ESMR) licenses and integrated Digital Enhanced Network (iDEN) technology, Nextel offers a unique dispatch feature called Direct Connect. This feature enables mobile business groups to enter wireless conferences instantly.[5] Direct Connect is reported to account for half to two-thirds of Nextel's network traffic.[6] Although other digital wireless technologies may in time develop a similar feature, they are likely to incur substantial time and cost to do so.[7] Meanwhile, consumers have an (evidently valuable) option available that would not likely have been available had the U.S. government mandated any of the leading contenders for "the" second generation wireless standard.

We am not suggesting that Nextel's technology is therefore the "best." On the contrary, our point is that, because users' needs differ, there is no such thing as "best." Thus, other second generation digital wireless technologies have provided different features that are valued by some subscribers.

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5 Nextel Communication Inc., 10-K, December 31, 1997, pp. 3–4; Prudential Securities, *Wireless Technology Report*, May 20, 1998, p. 7.

6 Donaldson, Lufkin & Jenrette, *The Wireless Communications Industry*, Spring 1998, pp. 37–38.

7 Prudential Securities, *Wireless Technology Report*, May 20, 1998, p. 33; Donaldson, Lufkin & Jenrette, *The Wireless Communications Industry*, Spring 1998, p. 37.

For example, some GSM handsets use a removable "smart card," known as a Subscriber Identity Module (SIM), which contains subscriber account information, personal phone lists and security parameters. These smart cards allow GSM operators to offer their customers a unique form of roaming across various GSM networks that use different bands of spectrum. A subscriber removes the SIM from his own phone and inserts it into a phone designed to work in the appropriate local frequency spectrum.[8] Thus, travelers may be able to avoid carrying multi-band phones; the downside of course is that they must find a phone into which to put their SIM. Another unique feature of GSM is that it is the only second generation standard that is ISDN compatible.[9]

Multiple standards allow service providers to meet the needs of different market segments. There are many distinct applications for wireless technology, including mobile voice, paging and messaging, high-speed data transmission, multimedia, wireless local loop, service in remote hard-to-cover areas and no doubt others that have not yet been discussed. The efficient choice of which such services to offer depends on demographics, the price and quality of landline service, spectrum availability and other factors, and different consumers will demand different mixes of services. Consequently, different operators will efficiently want to offer different mixes or selections of these new applications.

A well-designed single standard tries to allow for the flexibility to support multiple and diverse applications. However, any particular standard may fail to do so optimally.

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8 Strategis Group, *3G Wireless: Demand, Standards, and Technology*, June 1998, p. 69.

9 Strategis Group, *3G Wireless: Demand, Standards, and Technology*, June 1998, p. 70; Jerry Blake "PCS Providers Look to GSM to Differentiate Mobile Data Service", *RCR Wireless News*, September 9, 1996.

Moreover, as we discuss below, there is an inherent problem with a consensus process, a government, or any single decision-maker setting the boundaries of flexibility for the market. That problem can be avoided if multiple standards compete with one another.

Multiple standards also give service providers technical choices that allow the frequency spectrum to be used efficiently. In some densely populated regions of the country, spectrum is scarce, and the locally optimal technology uses spectrum parsimoniously, even if this is costly. In other regions, spectrum is much less scarce, perhaps even to the point where buildout is questionable,[10] and in such areas, low buildout costs are a more important criterion than technically efficient spectrum utilization.[11] In still other regions, transmission quality or the availability of multiple features may be the key consideration. If different standards co-exist, service providers can more efficiently tailor their choices to local conditions.

Finally, the debate over alternative third generation standards suggests that different third generation wireless standards impose significantly different upgrade costs on operators with different second generation networks in place. Thus, there is a potentially significant cost saving from allowing each operator to choose the standard that minimizes its upgrade costs. The end result of allowing these kinds of variety is that consumers benefit from greater wireless availability and lower prices.

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[10] In January 1997, the FCC auctioned licenses to areas still unserved even by analog cellular. FCC website: http://www.fcc.gov/wtb/auctions/summary/aucsum.pdf. It seems at least plausible that the best prospect for buildout in those regions is the cheapest possible buildout, even if some features and quality are sacrificed.

[11] 21st Century Telesis is planning to use a technology called Personal Access Communications System (PACS) with its PCS licenses. Proponents believe that PACS, a low-power microcell technology, can be installed at lower costs than other high-power digital technologies. *See* Lynnette Luna, "21st Century Grooming First PACS Deployment," *RCR Radio Communications Report*, December 29, 1997.

Weighing these various local factors, together with the possible coordination benefits from sharing a technology with other service providers (especially in other areas), is a highly complex problem. Unless there is good evidence that private decisionmakers — the service providers — will badly fail to balance the various considerations, it would be highly unwise for government decisionmakers to substitute their judgment for that of the parties with the strongest incentives to get it right.

B. Technology Competition and Innovation

As some of these examples of the benefits of variety attest, competition among standards can spur leapfrogging innovation, in which the proponents of each standard try to be the first to introduce new features, and try to catch up with and surpass others who have done so. When faced with competition from other technology alternatives, proponents of each standard find it profitable to invest in making their standard more attractive.

For example, rivalry between the competing VCR formats, Betamax and VHS, spurred leapfrogging innovations that increased playing times dramatically between 1975 and 1982. While Beta started with one hour of playing time in 1975 and VHS started with two hours in 1976, Betamax matched the VHS technology's two hours shortly thereafter. By 1979, the VHS technology offered playing times of six hours and by 1982, Beta was offering eight hours of play.[12] Albeit at the cost of some temporary confusion, competition between the VHS and Betamax standards spurred innovation in both technologies.

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[12] Michael A. Cusumano, Yiorges Mylonadis and Richard S. Rosenbloom, "Strategic Maneuvering and Mass-Market Dynamics: The Triumph of VHS over Beta," *Business History Review*, Spring 1992, p. 77.

Similarly, several different technologies compete with one another in the high-speed local-area networking market. LAN standards include Ethernet, Token Ring, and FDDI. Each of these standards serves different types of user needs. Competition among these standards has led to the development of newer standards with greater bandwidth and more features including Fast and Gigabit Ethernet, ATM and Fibre Channel.[13]

Innovation is extremely important in wireless telecommunications technology. In less than ten years, wireless transmission technology has dramatically improved, with more efficient spectrum utilization, increased capacity, higher quality voice transmission, many new features (paging, fax, e-mail, voicemail, worldwide web access, conference calls), fewer security problems, smaller and better handsets and lower prices. Competition between second generation standards has spurred leapfrogging technological improvements. The original CDMA speech coding (vocoder) technology provided inferior voice quality to TDMA. In response, several improved vocoder technologies have been developed for CDMA. In turn the TDMA vocoder has also been improved.[14] As another example, manufacturers of second generation equipment are currently working to increase the data throughput speeds of TDMA IS-136, GSM and CDMA.[15]

Indeed, CDMA itself is an example of the value of not mandating a standard. In the early days of second generation wireless, the industry advocated making TDMA the U.S.

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[13] Electronic Trends Publications, Inc., *The Worldwide Market for High-Speed LAN Products*, 1998.

[14] *See, e.g.*, Debra Wayne, "CDMA Waiting Continues On," *RCR Wireless News*, May 13, 1996; Elizabeth V. Mooney, " 'Religious' Technology Wars Continue as TDMA Seeks Converts," *RCR Wireless News*, February 17, 1997.

[15] Strategis Group, *3G Wireless: Demand, Standards, and Technology*, June 1998, pp. 67-70.

standard, but the FCC did not mandate its use.[16] As a result, innovators were free, and had incentives, to develop and commercialize code-division technology.

C. Keeping Options Open in the Presence of Technological Uncertainty

Allowing multiple standards keeps options open in the presence of technological uncertainty and allows services to be offered based on the best technology available without locking out improved technology in the future. Keeping technological options open is important when there is significant uncertainty regarding the relative performance of competing standards and relevant information is arriving or being developed over time. In such a case, mandating a standard involves deciding when to pick a standard, as well as which one to pick, and both of these are very difficult decisions, unlikely to be made well by government agencies.

In wireless telecommunications, there has been rapid and somewhat unpredictable technological progress. For example, when CDMA was first commercialized, Qualcomm reportedly indicated that CDMA would have up to 40 times the capacity of analog systems.[17] However, the capacity advantages of second generation CDMA turned out to be smaller than that prediction, and even now there is dispute as to the numbers.[18]

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[16] Eric Schimmel, "TIA Hopes Its Standards Efforts Contribute to Orderly Evolution," *RCR Wireless News*, January 30, 1995.

[17] "Qualcomm Exec Argues WSJ Story," *RCR Wireless News*, October 7, 1996.

[18] The capacity gain has been reported recently as 8 to 10 times analog. "CDMA Technology & Benefits" Motorola website: http://www.mot.com/CNSS/CIG/Technology/cdma.html; It has also been reported as 10 to15 times analog. "3G Wireless: Demand, Standards, and Technology," *Strategis Group Report*, June 1998, p. 23.

Similarly, there appears to be much uncertainty about the relative technical merits of proposed third generation standards. For example, Qualcomm and Ericsson dispute the technical merits of cdma2000 and W-CDMA along many performance dimensions.[19] In addition there is considerable uncertainty about subscriber demand for third generation features, and therefore just which technical capabilities will be most important in the future.[20]

From the point of view of policymakers considering whether to mandate a standard, it makes little difference whether the uncertainty reflects genuine scientific uncertainty, differences of view among experts, or whether some or all are being disingenuous. One way or the other, there are conflicting claims about the relative merits of proposed standards, and policymakers who mandate a standard will do so "in the dark." If engineers disagree on the merits of the competing standards, it would be optimistic to expect governments to make wise choices in the face of such uncertainty.

D. Reduced Need for Regulatory or Consensus Control

Another potential benefit of multiple standards is that competition among standards reduces the need for regulatory or consensus control of the standards management process. The issue of standards management arises because standards by their nature constrain design

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[19] Qualcomm claims that certain features of cdma2000, including the 3.6864 Mcps chip rate, synchronous base station transmission, Code-Division Multiplexed pilots and true variable rate vocoding are superior to the corresponding features of W-CDMA. *See* "The Technical Case for Convergence of Third Generation Wireless Systems Based on CDMA," Qualcomm website: http://www.qualcomm.com/cdma/tech/3g_5points.shtml. Ericsson, on the other hand, claims that the advantages of W-CDMA include its 4.096 Mcps chip rate that optimizes system capacity and performance and its asynchronous base station operation that is independent of GPS satellite systems. Ericsson further claims that cdma2000 has fundamental limitations compared to W–CDMA because of its channel format, common pilot channel structure, lack of support for interfrequency handover, inefficient support for bit-rate and service flexibility and lack of an integral TDD mode. *See* "Position Statement: Wideband CDMA (WCDMA)," IMT-2000 Ericsson in Wideband Wireless Multimedia website: http://www.imt-2000.com/wcdma/news/position.htm. On this general topic of dispute, see also May 19, 1998 letter from Gary Jones of Omnipoint to Dale Hatfield, FCC.

[20] *See, e.g.*, Lynnette Luna, "Is There a Need for 3G," *RCR Wireless News*, April 7, 1998.

and behavior to some extent. Even a voluntary industry consensus standard, or a standard adopted purely by decentralized decisionmaking, can be said to constrain if coordination is sufficiently valuable to each industry participant; a government-mandated standard by definition constrains more strongly.

In a dynamic, innovative industry such as wireless, this creates a serious problem: How is the standard to be managed? In particular, who controls what innovations are introduced and whether those innovations are licensed to participants other than the innovator and on what terms?

As we briefly discuss below, there is no practicable ideal solution to standards management within a single standard. Consequently, it is extremely valuable to have competition from (actual or potential) other standards, if it can be sustained without gross inefficiencies. Absent such competition, there is much more threat of inefficient or anticompetitive outcomes. Moreover, in attempts to avert that threat, cumbersome and potentially inefficient consensus or regulatory solutions are often (wisely or not) adopted, which themselves can retard innovation and limit flexibility.

In the computer industry, Microsoft and Intel control many key decisions through their control of the Wintel standard. As every newspaper reader is aware, there is widespread concern about this private for-profit control of a standard that is so widely adopted in our society. Complaints abound, justified or not, about this private management of the rules of the road for a key part of the computer industry. Clearly, the concerns would be far greater if the actual alternatives, such as Unix-based systems and Apple, disappeared and we had only

the *possibility* of alternative platforms. Consider how much more severe still the competitive concerns would become if compliance with the Wintel standard were *mandated*!

One possible alternative to letting private firms (such as Microsoft and Intel) manage a standard is direct government management. This solution is used, for example, in television standards. However, direct government control creates a new set of problems. First, absent compulsory licensing, government control of a standard may unacceptably create a government-protected monopoly for the firms holding essential intellectual property for practicing the standard. Second, government control can be slow and unwieldy, notably in the U.S., with its culture of stringent oversight and challenge of government actions. Third, a government mandate is not necessarily immune to undue influence from vested interests. Fourth, due-process rules and substantive protections to safeguard against parties using the standard for anticompetitive purposes — including vigorous exercise of intellectual property — can create other problems, notably slowness of response to new technological opportunities.

Another model of standards management is private consensus management. Consensus management can of course differ in how closely it specifies technology, but if a great deal of latitude is provided, then the interoperability benefits that presumably motivate having the standard may dissipate.[21] On the other hand, a consensus management system that protects the standard against fragmentation will almost inevitably give collective decision-making (whether voting, the search for unanimity, or some other collective decision

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[21] For example, in the Unix operating system multiple "flavors" of Unix developed over time, creating fragmentation and incompatibilities *within* the Unix standard. *See* H. Landis Gabel, "Open Standards in the European Computer Industry: The Case of X/Open," in H. Landis Gabel, ed. , *Product Standardization and Competitive Strategy*, 1987, Amsterdam: North-Holland Press, pp. 91123 and Garth Saloner, "Economic

rule) a prominent role in determining the industry's technological direction. This raises antitrust concerns[22] and also simply makes it harder to change any inefficiency. To guard against anticompetitive uses of the consensus standards process, most consensus standards bodies, including ANSI, ETSI, and the ITU, have strict rules of due process that apply to changes in the standard (as well as to initial adoption).[23] In general, they require a prolonged search for "consensus" before going ahead against sustained objections from any substantial segment of the industry. This raises the threat that established interests might delay and deter technological changes within the standard that threaten them competitively. And the more competitive the industry becomes, the more the parties' interests are likely to diverge.

Similarly, to guard against conferring an unregulated monopoly on holders of intellectual property, private standard-setting bodies have policies for nondiscriminatory and "reasonable" licensing of essential intellectual property that is, by consensus or vote, included in their standards. Again, given the problem of managing an industrywide standard — even a voluntary one, and *a fortiori* a mandatory standard — such a policy may be wise. But it clearly can constrain the rewards available to a successful innovator, and may well thus discourage major innovation.

Issues in Computer Interface Standards," *Economics of Innovation and New Technology*, vol. 1, no. 1-2, 1990.

[22] Antitrust concerns are defused in some part by the voluntary nature of complying with many consensus standards; antitrust issues would arise with greater force in mandatory standards.

[23] For discussion of antitrust issues in standard-setting, see for instance James Anton and Dennis Yao, "Standard-Setting Consortia, Antitrust, and High-Technology Industries." *Antitrust Law Journal*, 64:1, Fall 1995, at 247; and Oliver E. Williamson and Richard J. Gilbert, "Antitrust Policy", in *New Palgrave Dictionary of Economics and the Law*, Macmillan, 1998.

We do not mean to suggest that these management policies are unwise. Rather, they are inevitably imperfect resolutions of very thorny problems. It is thus highly desirable to be able to bypass their inevitable imperfections by allowing multiple (separately managed) standards to compete against one another, unless grossly inefficient failures of interoperability result.

As with competition in general, competition among standards protects society in two ways. First, it improves the incentives facing participants in each standard: they must compete to make it more attractive than other standards. And, second, even should that incentive effect sometimes fail, users have a choice.[24]

The presence of lively competition from outside a given standard, then, makes it less worrisome how any individual standard is managed. It thus enables each standard to be managed according to less regulatory and more market-like principles, without so grave a threat of monopolization or of gouging by holders of intellectual property.

In particular, when multiple technologies compete, each technology's sponsors can innovate more freely, and may have more freedom to charge royalties closer to the value created by their innovations. Consumers are protected against overcharging not through cumbersome regulatory or broad-consensus control, but rather through the market mechanism. And manufacturers are provided with what is likely to be more efficient incentives for innovation, because there is less need for careful regulation of royalty payments.

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[24] As a hypothetical example, if the management processes of two competing third generation wireless standards were to delay implementing new wireless local loop technology (either because incumbent local exchange carriers are influential, or just through inadvertence), but that of a third standard does not delay, the technology becomes promptly available despite the two failures.

In sum, there are many potential benefits of allowing multiple standards to compete in the marketplace. Thus, policy makers should be very cautious about mandating a single national standard and sacrificing these important social benefits.

III. Are There Benefits of a Mandated National Third Generation Wireless Standard?

Some argue that a single industry standard could benefit wireless consumers by facilitating seamless *roaming* by subscribers traveling outside their regular service area and by reducing costs as firms take advantage of *economies of scale*. As a general matter, we certainly agree that there can be benefits of a single standard in some circumstances, to be set against the important costs discussed above. However, examination of the wireless industry indicates that efficient roaming and scale economies can likely be realized even with multiple standards surviving in the industry.

Thus, we see no need for a single national standard, let alone for a government mandate, in this case. A *mandated* single standard is only called for when there are major benefits of a single standard that are not taken into account by market participants in their decision making, and these benefits are important enough to outweigh the significant efficiency costs involved in mandating a single standard. In the case of third generation wireless, this condition does not hold.

A. Roaming

Roaming allows wireless subscribers to use their handsets outside their regular service area. For roaming to take place, a subscriber's handset must be compatible with "enough" base stations in the area in which she is traveling. Thus, roaming requires a limited form of interoperability between base stations in different geographic areas.

As a general matter of economic theory, we identify two possible scenarios where firms might inefficiently fail to achieve convenient roaming — which is of course a necessary condition for contemplating a mandate for this reason. The first scenario is if each operator fails to internalize a major fraction of the benefits from easier roaming, creating an *incentive problem*. The second scenario is if the sheer number of decision-makers and near-simultaneous decision making creates difficult *coordination problems* among geographically disparate operators. It may be that either or both of these conditions held in first generation Europe and possibly even in early second generation U.S. wireless, but they will not hold in the case of third generation U.S. wireless. Thus mandating a standard in order to facilitate nationwide roaming would be pointless — at best, it would be fighting the previous war.

This conclusion is based on several factors. First, service providers are keenly aware of consumer demand for roaming and thus likely to take it into account in their decisions about adopting technology.[25] Roaming revenues, which the CTIA did not even report in its first surveys, stand at about 11% of total revenues, according to the most recent CTIA *Wireless*

[25] Trade publications and analyst reports make it cery clear that operators are keenly aware of the potential benefits of roaming.

Industry Report.[26] The report also notes that this understates the true importance of roaming, because of the growth of roaming agreements under which operators do not bill one another and the growth of service plans, such as those offered by AT&T and Sprint, which provide nationwide access without roaming fees.[27] Moreover, the current marketing campaigns of AT&T, Sprint, and Nextel highlight the benefits of easier and cheaper roaming.[28]

Second, and perhaps most important, several major wireless providers currently have nationwide or near-nationwide license footprints. Service providers with nationwide footprints internalize the benefits and costs of national roaming, so that the *incentive problem* scenario identified above does not apply.

To illustrate the incentive issue, consider two service providers in separate locations between which there is enough travel that there is a demand for roaming. If Provider A in Atlanta chooses a technology that facilitates roaming to and from Boston, it affects roaming revenues and the demand for roaming in both Atlanta and Boston. Provider A of course captures the increased roaming revenue from Bostonians visiting Atlanta. She also captures some part of the increase in value for Atlanta-based consumers that is created by the fact that roaming is now easier for them when they visit Boston; the remainder of this increase in value

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[26] Cellular Telecommunications Industry Association, *CTIA's Wireless Industry: Semi-Annual Data Survey Results*, June 3, 1998, p. 4.

[27] Such agreements create a benefit for each operator (it can offer roaming to its customers), but this is in no way captured by the "roaming revenues" statistics, unlike the case where each operator separately charges for roaming. Even in the latter case, if operators reciprocally reduce their roaming prices, the roaming revenue statistics will understate the importance of roaming to an operator. *See* Cellular Telecommunications Industry Association, *CTIA's Wireless Industry: Semi-Annual Data Survey Results*, June 3, 1998, p. 31.

[28] *See, e.g.*, Kristen Beckman, "No Roaming Charges is Key to AT&T's One-Rate Calling Plan," *RCR Wireless News*, May 11, 1998; Lynnette Luna, "Battle for High-End Wireless Users Begins," *RCR Wireless News*, October 5, 1998.

is captured by Provider B through increased roaming revenues.[29] Symmetrically, Provider B may capture some part, but only some part, of the increase in value for Boston-based consumers visiting Atlanta (this is part of the increased roaming revenue), but does not capture the increased roaming revenues in Boston. However, all these gains are captured by the two providers considered jointly.[30]

This analysis suggests two possible incentive problems when Providers A and B make wholly independent decisions. First, each captures only part of the gains from technologically easier roaming. Second, each captures only part of the gains from reducing the price of roaming.[31] Both of these possible incentive problems disappear when the providers become one (especially when each must compete for customers) or when they carefully negotiate a contract that specifies technology choice and roaming prices.

Turning from incentives to coordination, each provider or alliance with a nationwide footprint can readily make technology choices that facilitate roaming on its own network without the need to coordinate roaming agreements among large numbers of geographically disparate providers. Thus, the *coordination problem* scenario does not obstruct efficient nationwide roaming either. Given the existence of three carriers licensed for nationwide

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[29] To see why Provider A captures that part of the increase in value that Provider B does not capture, note that A's marginal customer pays a price to Provider A that includes the quasi-surplus generated by the ability to roam to area B. The fact that providers often advertise roaming arrangements indicates that their marginal, as well as inframarginal, subscribers value roaming substantially.

[30] Consumers benefit when there is competition, and then these benefits (to the extent they exceed costs) are passed through. This does not change the fact that Operators A and B face correct incentives, however.

[31] When prices are set noncooperatively, if provider A reduces the price of roaming in Atlanta, Bostonians visiting Atlanta become better off, and provider A does not (directly) internalize this gain. However, as noted above, provider B does capture this effect (to the extent that it applies to B's marginal customer). Thus, careful negotiations, or integration, between the providers will yield efficient incentives. Unfortunately,

footprints, and of a number of others with large footprints, efficient nationwide third generation roaming can be expected to develop without the need for a single (let alone for a mandated) national standard.

Specifically, according to the recent FCC report on competition in the wireless industry,[32] AT&T, Sprint PCS, and Nextel each has licenses covering at least 230 million POPs. Each of these firms can ensure, through *internal* decisions, that seamless roaming is available on its network. Forcing them (and all other wireless providers) to use *one and the same* standard is thus unnecessary for national roaming.[33] In addition to these near-nationwide footprints controlled by single firms, there are a number of firms and alliances with large footprints,[34] so modest private coordination efforts should be able to coordinate their technology choices, to the extent that common technology is the key factor in roaming.[35] Thus, the prospects for coordinated action among very manageable numbers of decision-makers are excellent. Such private coordination efforts need not involve (and thus

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such negotiations among a large number of providers may be difficult; hence the role of alliances and integration.

[32] Federal Communications Commission, *Third Annual CMRS Competition Report*, 1998, p. 22.

[33] Each of these carriers appears determined to build its own network at least to the extent required so that roaming is possible. Otherwise, there could be an interim gain from a single standard — not necessarily requiring a mandate — if there is an interim period during which they have built out to different areas, and if multi-mode phones are a poor solution. However, inspection of S*trategis* maps of where second generation service will potentially be available under various standards suggests more overlap than complementarity of buildout. Strategis Group, *3G Wireless: Demands, Standards, and Technology*, June 1998, pp. 44-46.

[34] The FCC report indicates that PrimeCo has signed a roaming agreement with Bell Atlantic and Airtouch that covers two-thirds of the nation's POPs, including 35 of the top 50 cities, and that the North American GSM Alliance of 13 PCS providers facilitates roaming throughout North America. Federal Communications Commission, *Third Annual CMRS Competition Report,* 1998, p.23.

[35] If existing large footprints are not enough, demand for nationwide roaming would create incentives for further consolidation across geographic lines if that were the key to smooth roaming. Such consolidation is not frictionless, but it is certainly possible.

constrain) the whole industry, nor need they involve a government mandate, which would much more severely constrain the whole industry.

Third, multi-mode phones offer a viable technical solution for nationwide roaming. A multi-mode phone allows a subscriber to convert his handset to different standards or frequency bands depending on where he is traveling. Even if a customer travels to an area where no operator uses the same standard as his home service provider, he can still roam if he has a suitable dual-mode (or multi-mode) handset and roaming agreements are in place. Multi-mode phones that convert between analog and digital service are currently widely available, as are multi-band phones that convert between different radio frequencies.

Although multi-mode phones are modestly more expensive than single-mode phones,[36] we understand that the difference is a matter of an additional chip, a cost that is likely to come down considerably with volume production. Moreover, at least for nationwide service, the cost of multi-mode phones (including the subjective cost to consumers of any additional weight, etc.) will be internalized as part of a nationwide service provider's overall pattern of technology adoption. If multi-mode phones are a "clunky" solution to the roaming problem, nationwide operators have the right incentives (given that they compete for customers) to choose between that solution and a single-technology solution with potentially greater network costs. Thus, for example, AT&T is offering a tri-

[36] A recent DLJ report estimates the incremental cost of a multi-mode phone to be about $75. Donaldson, Lufkin & Jenrette, *The Wireless Communications Industry*, Spring 1998, p.23.

mode, dual-band phone to its customers,[37] in preference to rebuilding its entire network to a single second generation standard. If multi-mode phones were an inefficient choice, customers' demand for AT&T's service would reflect the inconvenience, and AT&T would have an incentive to reconsider its tradeoff between multi-mode phones and network costs.

Indeed, Sprint has chosen to overbuild APC's GSM network in the Washington, DC, area with a CDMA network, rather than have to impose multi-mode phones on its roaming customers.[38] If Sprint and AT&T disagree over the efficient way to manage the tradeoff between network costs and multi-mode phones, it is surely not a simple problem to which policymakers can well mandate an answer.

Although our discussion here concerns nationwide roaming, it may be worth noting that, because of conflicting spectrum policies, international roaming is likely to require multi-band phones, independent of national or international technology standards policy.[39] Moreover, a recent ETSI document indicates that the added complexity of dual modes is "insignificant", and that the real cost and complexity arise from developing handsets and base stations that can work across different frequency allocations and bandwidths.[40] It is also important to note that only a relatively small number of U.S. customers are likely to require

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[37] AT&T Wireless Services website: http://www.attws.com/nohost/cellular/ce_phn7.html; Dual Band/Tri-Mode D-Amps Phones Make Coverage Problem Obsolete," *Ericsson Wireless Now!*, Ericsson website: http://www.ericsson.se/wn/wn1-98/obsoleteprob.html.

[38] "Sprint Spectrum Offers CDMA in D.C.," *RCR Wireless News*, April 13, 1998.

[39] Although at the 1992 World Administrative Radiocommunication Conference the ITU identified the bands 1885-2025 MHz and 2110-2200 MHz for third generation services, these frequencies are already partially in use in different parts of the world, including in the U.S. *See, e.g.*, Lynnette Luna "FCC Mulls Allocating More Spectrum for 3G" *RCR Wireless News*, August 31, 1998.

[40] "On the Implementation of a Global 3rd Generation Terminal," ETSI SMG2 #26, Marseille, France, September 21-25, 1998.

international roaming, which makes it more likely that multi-mode phones rather than single standards would be the efficient solution.

Fourth, although currently expensive, satellite systems provide another technical solution that can facilitate roaming. Low earth orbit (LEO) satellite systems, like Globalstar, Iridium, ICO, Ellipso, and ECCO serve as complements to terrestrial digital wireless by facilitating roaming to areas not served by terrestrial systems. A recent Lehman Brothers report[41] describes satellite handsets designed to first attempt to make a terrestrial digital call and only default to a more expensive satellite call when necessary.

Finally, it has been suggested that the multiple second generation standards deployed in the U.S. will tend to carry over into multiple third generation standards because of large differences in upgrade costs between upgrading to a "compatible" third generation standard and to an "incompatible" one.[42] As noted above, such differences in upgrade costs are economically analogous to variety in preferences. If these differences are indeed large, then they should be accorded corresponding weight in policy decisions, just as they are in business decisions.

In any event, such cost differences in upgrading to a particular third generation standard from different second generation networks need not obstruct nationwide roaming. Each of the main second generation standards is already planned to be widely deployed in the

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[41] Lehman Brothers Equity Research, Wireless Services and Satellites, "The Conquest of Coverage", *Bensche-Marks* Vol. 98-09, September 8, 1998.

[42] Here, "compatible" and "incompatible" describe how much network infrastructure is shared between the second generation and third generation standard: a "compatible" upgrade is one in which more network infrastructure is shared and less needs to be replaced.

U.S., with a near-nationwide footprint. Thus, even if each operator's second generation choice strictly determined its third generation choice, and even if we ignore licenses to which no second generation choice has yet been committed, and even if we ignore multi-mode phones, technology incompatibility need not obstruct national third generation roaming. Rather, nationwide roaming would be possible within each standard.

In summary, there is every reason to believe that consumer demand for nationwide roaming will be met by third generation wireless service providers responding to profit opportunities. No single industry-wide standard, let alone a government mandated one, is necessary to ensure it.

B. Production-side Economies of Scale

In an industry with sufficient production-side standard-specific economies of scale over a wide range of output, the total costs of producing a given number of units may be lower with a single standard than with multiple standards. Although the presence of such standard-specific production-side economies of scale would make it more likely that *having* a single standard is efficient (relative to having multiple standards), it does not in itself argue for *mandating* a standard, since private decisionmakers will normally take economies of scale into account themselves. In any case, evidence in the wireless manufacturing industry indicates that such economies of scale are limited and can be achieved without a single standard.

An argument for mandating a standard in order to achieve economies of scale must demonstrate three things:

(a) the economies of scale are unlikely to be correctly internalized by market participants, *and*

(b) the economies of scale are standard-specific, *i.e.*, will not be realized if an equal quantity is produced but on several standards, *and*

(c) the economies of scale are large relative to the size of the market and relative to the inefficiencies of a mandated standard.

There is no good evidence that any, let alone all, of these conditions hold in the case of third generation wireless standards.

Internalizing economies of scale. The usual case, and the reason why it is generally bad economics to mandate that everyone should buy the same thing so as to realize economies of scale, is that economies of scale are taken into account by sellers and buyers. That is, in the usual case where scale economies are firm-specific — it is the firm producing a larger quantity that incurs lower costs — then bigger firms can make better offers to buyers than can smaller firms. As a result, if competition to offer the best value to consumers is intense, small firms will grow or die, and economies of scale will be realized, without any need for intervention.[43] By the same token, the survival of many firms in an industry with stiff competition suggests that no very great firm-specific economies of scale exist beyond the scale of most firms in the industry.

Competition among manufacturers makes it unlikely that there are large unrealized firm-specific economies of scale in second generation wireless equipment. First, as shown in

[43] Firms will stay on steeply downward-sloping portions of their average-cost curve only if they have market power or in conditions of "monopolistic competition" where firm-specific elasticities of demand are small, *i.e.*, where a price reduction would not bring in enough additional business to create commensurate cost savings.

Table 1, there are multiple firms supplying handsets and network equipment for each second generation standard. Second, multiple second generation wireless standards compete against one another. Third, most buyers in the wireless equipment market are large and sophisticated service providers, and the equipment purchase is an important one for service providers, with a significant impact on the bottom line,[44] so one can surely assume they carefully scrutinize the value offered by competing equipment suppliers.[45] Thus, the wireless manufacturing industry appears to be quite competitive, making it unlikely that there are large unrealized firm-specific economies of scale.

There is also evidence that economies of scale that *are* present are not wholly standard-specific. As Table 1 indicates, many wireless manufacturers produce to more than one standard. Although this would be a possible pattern in the presence of limited standard-specific scale economies, there would be no evident reason why firms would not specialize in one standard.[46] These production patterns suggest that at least some economies of scale are *not* wholly standard-specific. The significance of this is, of course, that a single standard reduces production costs *only* if the otherwise unrealized economies of scale are standard-specific.

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[44] Network equipment is of course purchased by service providers. Moreover the common practice of bundling handsets with subscriptions or subsidizing consumer purchases of handsets means that handsets are also effectively purchased by service providers.

[45] We understand that competition is particularly intense to supply new contracts, and less so to provide upgrades for existing networks, where the firm who had the initial contract is thought to have a substantial advantage. Economists call this a pattern of "lock-in" or "switching costs". In a static or declining market, this may cause significant failures of competition. In a rapidly growing market (where there are many "new buyers" as yet uncommitted to a seller) it is less likely to cause problems. In any case, although it could potentially lead to unrealized firm-specific economies of scale, the same problem would be present under a mandated single standard, so this would not constitute an argument for such a standard.

[46] Specializing might also help persuade new buyers, who must make a considerable commitment to one standard, that a seller is committed to focusing on that standard.

We next consider the possibility of non-firm-specific, standard-specific, economies of scale. These are economies of scale shared among the part of the industry that produces to a given standard, but not such as to give a larger firm a cost advantage over a smaller one. Such economies of scale can in general be important, e.g., if a minority standard ceases to have the critical mass to sustain workable competition in equipment supply.

It is inherently more difficult to diagnose such economies than the ordinary firm-specific kind. However, if large standard-specific economies of scale are present at relevant scales, one would expect to see the dominant standard (GSM) in the world equipment market dramatically "pulling away from" others. On the contrary, it appears that despite CDMA's much smaller scale in the worldwide market, second generation CDMA is succeeding in making a substantial number of sales to new buyers.[47] This suggests that any standard-specific economies of scale (whether or not firm-specific) are quite limited relative to the advantages of variety and open innovation that CDMA represents — precisely the advantages that would be sacrificed under a mandated standard.

Combining all these observations, it is implausible that large standard-specific production economies of scale are unexploited in today's wireless equipment market and would be exploited with a mandated U.S. standard. In the much larger wireless equipment market expected in the future, economies of scale should be realized with multiple suppliers producing to a number of standards. Thus, there is no justification based on production-side economies of scale for a government mandate of a particular third generation wireless standard.

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[47] *See, e.g.*, "Fastest Growing Wireless Technology Hits 16 Million Worldwide Subscribers; CDMA Continues to be Most Dominant Standard in North America with 4.5 Million Subscribers," CDMA Development Group (CDG) Press Release, September 23, 1998, CDG website: http://www.cdg.org/press/sep23_98.html; "CDMA

In any event, if the policy decision is whether to mandate a U.S. standard, it is by no means clear that this will increase the extent to which global production adheres to one standard. Indeed, if a mandated U.S. standard departs from a standard adopted by much of the rest of the world, any effect on economies of scale would tend to go the other way.

IV. Standards Policy and Economic Efficiency

The primary consideration of a standards policy should be economic efficiency and the long-run interests of consumers, not the interests of specific manufacturers and associated claims about jobs. Mandating a standard in third generation wireless would have troublesome consequences for the efficiency and technological progressiveness of the wireless industry.[48] The wireless service industry is considerably larger than the wireless equipment manufacturing industry,[49] and, as discussed above, standards policy is liable to have major impacts on the wireless service industry. Consumers count too, of course, and their interests are aligned with the efficient provision of service. Finally, when service providers are able to choose the best technology for meeting their customers' needs from among multiple standards, they will be willing to pay more for spectrum, and to the extent

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Becomes World's Fastest Wireless Technology to Market," CDMA Development Group (CDG) Press Release, June 23, 1998, CDG website: http://www.cdg.org/press/jun23_98.html.

[48] This would also have spillover effects in wireline telecommunications regulation, to the extent that a less aggressive wireless industry would retard the full development of wireless local loop and "cutting the cord" as an alternative to incumbent local exchange carriers.

[49] A recent DLJ report estimates that worldwide wireless infrastructure investment will be about $23 billion per year from 1995–2001, while spending on handsets will be about $33 billion in 1998. This total of $56 billion for network infrastructure and handsets can be compared to estimated 1998 worldwide service revenue of $160 billion. Donaldson, Lufkin & Jenrette, *The Wireless Communications Industry*, Spring 1998, pp. 56-61; Federal

that further spectrum is auctioned (or re-auctioned),[50] the federal budget also benefits. These important considerations argue for facilitating efficient provision of wireless service, not for protecting manufacturers. It would thus be inefficient to set standards policy for third generation wireless based on a policy goal framed in terms of wireless manufacturing.

V. Mandated Standards and Manufacturing Interests

One claim in the debate over third generation wireless standards is that by mandating a particular standard, the U.S. government will be able to create many more U.S. manufacturing jobs and propel U.S. manufacturing firms into leadership positions in the wireless industry. We am very skeptical of this viewpoint. Manufacturing jobs and manufacturing leadership depend on manufacturing advantages, and do not simply rest in the country of origin of a standard.

First, the country of origin for a standard does not automatically translate into manufacturing advantages for firms based in that country. To take a well-known example, the NTSC color television standard was developed in the U.S., but the vast majority of NTSC color television manufacturing moved to Japan.[51] We have already seen such mobility of manufacturing advantage in second generation wireless:

Communications Commission, *Third Annual CMRS Competition Report*, 1998, Figure 1; International Telecommunication Union, *World Telecommunication Development Report, 1996/97*, February 1997.

[50] The FCC has proposed to re-auction parts of the PCS C-Block first Quarter 1999. *See* http://www.fcc.gov/wtb/auctions/aucsch.html.

[51] Development of the NTSC standard is described e.g. in Joseph Farrell and Carl Shapiro, "Standard Setting in High-Definition Television," *Brookings Papers: Microeconomics*, 1992.

- The TDMA/IS–136 second generation digital wireless standard is identified primarily as a "North American standard," yet the major vendors/ manufacturers of TDMA/IS–136 are Ericsson, Lucent, Nortel, Hughes Network Systems, and Nokia.[52]

- The second generation CDMA digital wireless standard was developed in the U.S., but as indicated in Table 1, many foreign manufacturers, including Sony,[53] Samsung,[54] Nokia and Siemens manufacture second generation CDMA handsets and network infrastructure equipment.

- The second generation digital GSM standard is identified as a "European standard," but the major North American manufacturers Lucent, Motorola, Hughes, and Nortel, and many Asian manufacturers produce second generation GSM equipment.[55] Under ETSI policy, any manufacturer is entitled to license GSM at a "reasonable royalty," [56] including manufacturers who did not contribute IP to second generation GSM.

Similarly, in third generation wireless, there is no reason to expect U.S. manufacturers to be excluded from producing to a "European" standard such as the one ETSI

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[52] "International Vendors & Carriers Join TMDA/WIN Industry Organization," December 6, 1996, UWCC website: http://uwcc.org/cgi-shl/dbml.exe?Action=Query&Template=/uwcc/news3.

[53] According to a September 1997 Sony press release, Sony had shipped more than 2.5 million CDMA phones from Sony's manufacturing facility in San Diego, California, a joint venture between Sony Electronics and Qualcomm. "Sony Extends Leadership Role in Advancing Benefits of CDMA," Sony News Release; Sony website: http://www.sel.sony.com/SEL/corpcomm/news/wtc/13.html.

[54] Samsung has won CDMA network contracts in China, Russia, Hong Kong and Latin America. Samsung also developed a CDMA PCS mobile phone which it exported to Sprint PCS in the U.S. Samsung website: http://www.sec.samsung.co.kr/news/cgi-bin/secnews.cgi?app=print&key=15&.

[55] Indeed, a letter from the ETSI Director General to Congresswoman Constance Morella states that for GSM the "major part of the registered essential Intellectual Property Rights emanate from US companies." See, Open letter to Chairwoman Morella from Karl Heinz Rosenbrock, ETSI Director General, June 19, 1998.

[56] ETSI requests owners of essential intellectual property rights to "grant irrevocable licenses on fair, reasonable and non-discriminatory terms and conditions under such IPR." If the intellectual property rights owner refuses, "the General Assembly shall request the European Commission to see what further action may be appropriate, including non-recognition of the standard in question." *See ETSI Intellectual Property Rights Policy.*

has selected. We understand that there is an intellectual property pool for ETSI's proposed third generation standard within which parties agree to cross-license without royalties. One would expect that membership of this pool would depend on having valuable intellectual property to cross-license. A recent ETSI report[57] documents essential or potentially essential intellectual property rights notified to ETSI. According to this report, Airtouch, Lucent, Motorola and Qualcomm contributed essential intellectual property to the UMTS standard. Thus, it is implausible that U.S. manufacturers would be effectively excluded from producing for the W–CDMA market. Similarly, it is unlikely that foreign manufacturers would be effectively excluded from producing for a U.S.-mandated standard (assuming that anything like a symmetric licensing policy was followed).

Even if domestically developed and sponsored standards conferred an important advantage on "domestic" *firms*, it would be naïve to assume that the manufacturing *jobs* would be domestically based. Jobs working for a manufacturer of a particular "nationality" are not necessarily jobs in that nation. Again, second generation wireless offers examples:

- European wireless manufacturers, such as Ericsson[58] and Nokia,[59] produce wireless equipment for the GSM standard in the U.S., as well as in the rest of the

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57 ETSI Special Report 000 314 V1.3.1.

58 Ericsson has plants throughout the world but manufactures its GSM handsets for the U.S. market in Lynchburg, Virginia. Ericsson has 8,000 U.S. employees and 100 locations throughout the states, including a manufacturing center in Morgan Hill, California, in addition to its plant in Virginia. Jeffrey Silva, "3G Dispute Offers Glimpse of Transnational Environment," *RCR Wireless News*, June 15, 1998; *Ericsson 1996 Annual Report*, pp. 32-33; September 1998 e-mail from Ericsson.

59 Nokia manufactures base stations in the UK, United States, Australia and China. "Nokia Expands its Base Station Production in Oula, Finland, " Nokia Press Release, Nov. 14, 1996, Nokia website: http://www.nokia.com/news-htmls/ntc_96114.html;"Nokia Company Overview," Nokia website: http://www.nokia.com/americas/zone/compover.html. "20 Millionth Nokia GSM Phone Sold in Europe," Nokia Press Release, March 18, 1998, Nokia website: http://www.nokia.com/news/news_htmls/nmp_980318f.html. "Nokia Interim Report: June 1996," Nokia website: http://www.nokia.com/company/finance/interim962/business_groups.html.

world. Asian-based wireless manufacturers such as Mitsubishi,[60] NEC,[61] Sony,[62] and Hyundai[63] have also set up facilities or joint ventures in the U.S.

- North American-based wireless manufacturers such as Motorola,[64] Lucent,[65] Qualcomm[66] and Nortel[67] have set up manufacturing facilities outside the U.S.

The bottom line is that manufacturing jobs are portable internationally, probably much more so than jobs providing wireless services. Requests to base standards policy on alleged employment advantages of nationally sponsored standards are unconvincing even on

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[60] Mitsubishi Wireless Communications Inc. is a joint venture between Mitsubishi Electric Corporation and Mitsubishi Corporation. The company is headquartered in Georgia and assembles its cellular and PCS products in the U.S. "New Analog Phone From Mitsubishi Wireless Communications Has Retractable Antenna For Exceptional Performance," Mitsubishi Press Release, February 9, 1998, Mitsubishi website: http://mitsubishiwireless.com/about.pressrelease.980209.html.

[61] NEC has manufacturing operations throughout the world, including a manufacturing facility in Hillsboro, Oregon. It is unclear where NEC produces its GSM products. See http://www.nec.com/necusa.html#1 and *NEC Worldwide*, NEC website: http://www.nec.co.jp/english/profile/annual/1997/world/world.html.

[62] Sony manufactures CDMA equipment in the U.S. through its QPE joint venture with Qualcomm. "Sony Extends Leadership Role in Advancing Benefits of CDMA" Sony News Release, September 10, 1997, Sony website: http://www.sel.sony.com/SEL.corpcomm/news/wtc/13.html.

[63] Hyundai recently formed the Hyundai Wireless Communications Division, headquartered in San Jose, California, to develop CDMA wireless handsets and base stations. The division has R&D facilities in Korea, San Diego, and Tokyo, Japan. Hyundai website: http://www.hea.com/heah2/wireless/home.htm.

[64] Motorola produces CDMA infrastructure equipment in Brazil, Korea, and the U.S. and has other wireless equipment manufacturing operations in England. Motorola's Cellular Infrastructure Group (CIG) has been manufacturing GSM equipment in Swindon, England since 1989 and its Swindon plant remains Motorola's worldwide manufacturing center for digital GSM communications infrastructure equipment. "Motorola to Expand GSM Manufacturing Workforce," Motorola Press Release, February 5, 1997, Motorola website: http://www.mot.com/CNSS/CIG/press/press_archive_1997/19970205a.html; "Motorola to Manufacture Cellular Infrastructure in the Republic of Korea," Motorola Press Release, Apr 3, 1995, Motorola website: http://www.mot.com/CNSS/CIG/press/press_archive_1995/19950403.html; "Motorola CIG To Open New Manufacturing Facility in Brazil," Motorola Press Release, Nov 24, 1997, Motorola website: http://www.mot.com/CNSS/CIG/press/press_archive_1997/19971124.html.

[65] Lucent has manufacturing facilities throughout the world, including 5 in the Asia Pacific region and China, 6 in the Caribbean and Latin America, and locations in Ireland, France, Poland, Germany, and Spain. *See*, Lucent website: http://www.lucent.com/what/international/.

[66] Qualcomm manufactures CDMA handsets in Brazil through its subsidiary Qualcomm do Brasil. *See* "Qualcomm do Brasil Establishes New Factory to Manufacture Qualcomm CDMA Digital Phones in Sao Paolo," *PR Newswire*, August 18, 1998.

[67] Nortel manufactures wireless equipment in Canada, Mexico and Brazil. "Nortel in Calgary," undated, Nortel website: http://www.nortel.com/home/press/1998b/Calgarybkgrnder.html; "Nortel to Manufacture Digital Wireless Telecommunications Systems in Brazil," July 1997, Nortel website: http://nortel.com/wireless/news/1997c/7_10_9797257Brazilmfg.html.

their own terms: "foreign" manufacturers can and do manufacture to "U.S. standards," and foreign and U.S. firms alike manufacture both in the U.S. and abroad. Thus, mandating a "U.S. standard" will not reliably create a lot of jobs for U.S. manufacturing workers.[68]

VI. Conclusion

Government-mandated standards for third generation wireless telecommunications would sacrifice many important benefits relative to a technologically open marketplace. Moreover, the main putative benefits of a nationally mandated third generation standard do not require there to be a single standard at all, and certainly not a government-mandated one.

[68] Even if a standards policy could create jobs for U.S. manufacturing workers, the relevant question is at what cost. Government policies aimed at creating specific jobs often do so only at considerable cost. For example, it is estimated that when the U.S. and Japanese governments negotiated voluntary export restraints in 1981 to preserve jobs in the U.S. automobile industry, each manufacturing job saved cost U.S. consumers $160,000. See Robert Crandall, "Import Quotas and the Automobile Industry: The Costs of Protectionism," *Brookings Review*, Summer 1984, pp. 8–16.