

TECHNICAL APPENDIX

This Appendix describes the methodology used to estimate the direct economic effects of the ITC's Exclusion Order on consumers and producers in the U.S. mobile wireless industry.¹ Our economic model identifies three distinct scenarios whereby “non-infringing handset solutions” would become widely available to consumers after either 1, 2 or 3 years, respectively. The calculations themselves are made using an Excel spreadsheet. The estimates presented in the text of our report use the specific parameter estimates described in this technical appendix and other cited third party sources.

Our estimates of direct harm are determined by a set of inputs such as market forecasts, economic parameter estimates and user-defined values that can be altered to change assumptions about the incremental effect of the ITC Order. For example, a default value for lost 3G handset sales in 2007 is chosen based on industry reports by Gartner and Bernstein Research. However, the analysis can accommodate alternative assumptions about the market response to the ITC Order.

A. OUR APPROACH

We take a “bottoms up” approach to estimating economic harm by first identifying the various consumer and producer groups that are affected by the Order and then adding the effects on individual groups together to arrive at a grand total. The analysis proceeds in three steps. First, we construct a baseline forecast of the mobile wireless industry absent the ITC Order using forecasts by industry analysts of mobile subscribers, prices of handsets, and average revenue from various services. Second, we predict the change in the baseline forecast caused by the ITC Order—specifically, the lost revenue from foreclosed economic activity. Finally, we compute the monetary value of the economic harm to consumers and firms resulting from the change in industry activity.

The ITC Order forecloses purchases of mobile wireless handsets and services that consumers would otherwise have made. To measure the resulting harm to consumers, we place a dollar-value on the difference between the value of those purchases to consumers and the cost to them of the purchases—what economists call “consumer surplus”—both with and without the ITC Order. Essentially, this measures the consumer counterpart to lost profit because it represents the additional value they would have received absent the ITC Order above and beyond the “cost” of producing that value.

¹ *The Costs of the ITC Downstream Exclusion Order to the U.S. Economy*, July 10, 2007. The paper itself looks at additional effects of the ITC Order, including lost spectrum auction revenue and forgone GNP growth. However, this Appendix focuses exclusively on how we estimated direct harm to consumers and producers.

The harm to producers in the mobile wireless industry caused by the ITC Order is more transparent. As a result of the importation ban, the affected firms register a change in their profits. That change in profits is our measure of the economic harm to those firms, or more specifically, to their owners.

It is assumed that, in response to the ITC Order, both consumers and producers will adjust their consumption and production plans, respectively, to best accommodate the exclusion of downstream products and do what they can to mitigate harm to themselves.

We measure the impacts on both groups relative to a baseline in which no ITC Order was imposed. Total lost surplus is found by simply adding together lost consumer surplus and lost profits—implicitly giving them equal weight.

Lost consumer surplus and producer profits occur in each period while the Order is in effect. We find the present value of each one of these streams using an appropriate discount rate. It is not known over what time period the Order will affect these markets since that depends on when, and if, a non-infringing handset solution appears in the marketplace before the expiration of the '983 patent. To accommodate this uncertainty, we calculate the effect of the ITC Order without the development of a non-infringing handset solution for one, two and three years. In addition, we estimate a 12 month recovery period during which the industry gradually returns to the baseline trajectory.

B. BASELINE FORECAST

Our baseline forecast reflects independent analysts' expectations of the evolution of wireless telecommunications in the United States from the second quarter of 2007 through the end of 2012. Specifically, we use forecasts of total and 3G subscriber lines, total and 3G handset sales, average revenue per user (ARPU) from mobile voice and data services and average revenue for third party content and related services.

Roughly speaking, analysts expect little growth in mobile subscribership now that the U.S. market is reaching saturation. Nevertheless, analysts see rapid growth in the number of 3G subscribers and the sales of 3G handsets—both in absolute terms and as a percentage of industry totals. In parallel, 2G subscribers and handset sales are expected to continue to fall, and to do so at an accelerating rate. For example, it is expected that 2G will account for only a small fraction of mobile subscribers by 2011. Mobile service ARPU is forecasted to remain flat for the next few years with the continued decline in voice revenue offset by an increase in data services realized by the greater utilization of these services and a growing base of 3G subscribers. Handset prices are expected to fall on average and for both 2G and 3G handsets specifically. We discuss each of our baseline forecasts below.

Number of mobile subscribers: We take an industry analyst's recent forecast of the number of 3G subscribers and mobile subscribers for 2Q2007.² We then grow that amount at the implied rate consistent with a forecast of subscriber levels given for 2011. The number of 2G subscribers is assumed to be simply the difference between the total and 3G time series.

Number of handsets sold: We estimate handset sales for 2G and 3G users in a quarter by applying a replacement rate for both 2G and 3G users to the subscribers from the previous quarter. To each of these figures for 2G and 3G handsets, we add the net subscriber growth from the previous quarter. The replacement rates for 2G and 3G handsets were chosen to approximate the level of 3G and total handset forecasts from The Yankee Group and an average time of 18 months between handset purchases.³

Mobile services ARPU: To forecast average monthly expenditure by mobile subscribers, we first took the total U.S. mobile carrier revenues for voice, data and ancillary products and services in 2Q2007 from a CIBC research report.⁴ We then divided this total by our estimate of total subscribers in 2Q2007 to arrive average revenue per user, or "ARPU." Using an estimated annual growth rate for ARPU reported in a HSBC report, we project the ARPU levels forward.⁵ We apportion a differential in ARPU of \$5 per month between 2G and 3G subscribers based on CIBC and HSBC research reports.⁶

Third-party content ARPU: We calculate revenue for third-party content from a forecast from Strategy Analytics.⁷ We sum up their forecasts of "premium" revenue for the "Browser Download Games," "Games," "Multi-Person Games" and "Other Download" categories. We divide this revenue by total wireless subscribers to estimate total mobile ARPU, then assume

² The Yankee Group, North American Mobile Forecast, April 2007.

³ To express the dynamics that govern the relation between mobile subscribers and handset sales, let S_t and H_t denote the number of subscribers and handsets sold in quarter t , respectively. Then, if the subscriber base is growing, the relationship between the two is given by: $H_t = (S_t - S_{t-1}) + S_{t-1} / q$, where q is the number of quarters between handset purchases in a steady state, *i.e.*, when $S_t = S_{t-1}$.

⁴ Exhibit 1, CIBC "US Wireless on Track to Deliver Strong Financial Results" September 21, 2006. The figure corresponds with estimates of industry ARPU given by the FCC—see FCC 06-142 ("Eleventh Report").

⁵ HSBC "Data Accelerator Mobile Data Ripples Across the Pond" May 7, 2007.

⁶ Exhibits 6 and 7, CIBC "US Wireless on Track to Deliver Strong Financial Results" September 21, 2006; HSBC (2007), *Ibid*.

⁷ Strategy Analytics, Cellular Data Market Forecast 2001-2011; The "premium" category excludes "transport" revenue which may be revenue collected by the carriers and not a source of revenue to the third party providers.

2G ARPU is \$1 per quarter⁸ and estimate 3G ARPU as the residual amount to generate the overall average.

C. INCREMENTAL EFFECT OF EXCLUSION ORDER

The Exclusion Order will change how the U.S. mobile wireless industry evolves over the months and years to come. We estimate those changes by forecasting our series for subscribers, handsets and content under the ITC Order and then comparing it against our baseline forecast. The difference between the two series is the incremental effect of the ITC Order, and the source of the economic impact on consumers and producers.

The ITC Order will reduce handset sales by preventing consumers from purchasing new 3G handsets or updated versions of grandfathered 3G handsets. At the margin, this restriction will cause some 2G subscribers who otherwise would have purchased 3G handsets and related services to remain 2G subscribers. For these consumers, their expenditure on data services will be reduced on average because 3G subscribers spend more than non-3G subscribers on such services. Finally, although we do not forecast that the ITC Order will slow the overall growth in the number of mobile subscribers, we do forecast that it will alter the mix of 2G and 3G subscribers by slowing the rate of increase in the later. As a result, the decrease in 3G handset sales drives the mix of 2G and 3G handsets and subscribers and, therefore, the incremental effect of the ITC Order. In our report we estimated the economic harm of the ITC Order for a low and a high number of lost handset sales. The values chosen were motivated by analyst reports that examined the effect of the ITC Order on 3G handset sales.

Gartner Research estimated that the ITC Order will result in 10 million to 20 million fewer handset sales in the second half of 2007.⁹ A report by Bernstein Research forecasted lost 3G handset sales for a one-year period to be as high as 36 million units.¹⁰ Based on these forecasts, we took values for quarterly lost sales of 3G handsets to be 5 million and 10 million units in 3Q2007. Thereafter, lost sales decreased at a rate of 0.5% per quarter reflecting the net effect of the impact of the ITC Order on the 3G sector.

The Gartner report also identifies the three categories of users that will account for these lost sales:

- Type I consists of current 3G subscribers who would have upgraded to a better handset absent the Exclusion Order, but who opt not to buy any new handset because the upgrade option is removed.

⁸ This is the cost of downloading two games to a handset. See <http://www.playphone.com/20for10-mobilegames/signup.aspx?>

⁹ *Qualcomm and Broadcom Must Resolve Patent Dispute Quickly*, Gartner Research Report, G00149593, June 14, 2007.

¹⁰ *Qualcomm: Cost of ITC Ban Could Be Greater to U.S. CDMA Carriers Than to Qualcomm, Increasing the Likelihood of Veto*, Bernstein Research, July 9, 2007.

- Type II consists of current 3G subscribers who, like Type I customers, would have upgraded to a better handset without the Order but instead purchase a 3G data card or a non-excluded device.
- Type III consists of 2G subscribers who would have upgraded to a 3G handset absent the Order but who instead buy a new 2G handset.

Because Gartner Research does not provide its own estimates, we make an educated guess as to the relative size of the three groups. We posit that Type I subscribers would account for the largest share of lost handset sales given their revealed preference for advanced 3G features. This group of subscribers would likely be particularly disappointed by the inability to buy an upgraded handset. We reason that Type II subscribers would account for only a small share of lost handset sales, if only because a personal computer-with-data-card is a poor substitute for a 3G handset. Based on these considerations, we assign 50 percent, 10 percent and 40 percent of the lost handset sales to subscribers of Types I, II and III, respectively.

Using these proportions, we then calculate the incremental effect of the ITC Order on two series: handset sales and number of subscribers.¹¹ For Type I subscribers, the only incremental effect of the Exclusion Order is lost handset sales. Type II subscribers are harmed because they must settle for a second-best choice instead of their first choice—an upgraded handset. We do not calculate any incremental effect on these subscribers because finding reliable sources for these sales has been difficult and the amount of lost surplus should be relatively small. Type III subscribers are harmed because they lost the opportunity to purchase their first choice of 3G handset sways them to remain 2G subscribers. These consumers continue to buy 2G handsets and the lost handset sales revenue is the differential between the higher value 3G handset that they intended to purchase and their second-best choice.¹² In addition, Type III subscribers purchase a lower level of service from carriers because they remain 2G voice subscribers.¹³

¹¹ Our analysis does not estimate any price effects from the ITC Order.

¹² We can use notation from an above footnote to , if we let L_t denote the lost 3G handset sales in a quarter t , then 3G handset sales and subscribers are given by the following equations where $H_t^{3G'}$ and $S_t^{3G'}$ are handset sales and subscribers with the ITC order in quarter t . Then we have $H_t^{3G'} = H_t^{3G} - L_t$ and

$$S_t^{3G'} = h_t^{3G} - (0.4)L_t + \left(\frac{q-1}{q}\right)S_{t-1}^{3G'}$$

¹³ Note that only 40% of the 3G handset loss affects 3G subscriber growth because only Type III subscribers are actually lost. The balance reflects delayed handset purchases or purchases of alternative devices. Given the handset price, carrier ARPU and third party ARPU forecasts, we calculate the effect of the ITC Order on revenues by multiplying the lost quantities by the appropriate prices. The lost revenues from handset sales, carrier service and third party content allow us to measure the lost consumer surplus and lost producer profits of firms.

For lost sales of 3G handsets, we estimate average handset prices from a CIBC research report.¹⁴ In order to derive an average price for 3G handsets, we apply a differential of \$45 between 2G and 3G handsets. For Type I subscribers, lost handset revenue is the average price of a 3G handset. For Type III, lost handset revenue is the price differential between 2G and 3G handsets. We take the difference in ARPU between 2G and 3G subscribers to be \$5 per month based on industry estimates of the increased utilization of data services when subscribers upgrade to 3G.¹⁵

More formally, let $\hat{p}_t, p_t, \check{p}_t$ denote handset prices, service ARPU and content ARPU, respectively, in quarter t . Superscripts will denote 2G and 3G while primes denote values under the ITC Order and R^C, R^H, R^T and R^I denote revenues to carriers, handset manufacturers, third party content providers, and network infrastructure vendors respectively. Lost revenues are given by:

$$\begin{aligned}\Delta R_t^C &= (R_t^C - R_t^{C'}) = (S_t^{3G} - S_t^{3G'}) (\hat{p}_t^{3G} - \hat{p}_t^{2G}) \\ \Delta R_t^H &= (R_t^H - R_t^{H'}) = (h_t^{3G} - h_t^{3G'}) ((.5)p_t^{3G} + (.4)(p_t^{3G} - p_t^{2G})) \\ \Delta R_t^T &= (R_t^T - R_t^{T'}) = (S_t^{3G} - S_t^{3G'}) (\check{p}_t^{3G} - \check{p}_t^{2G}) \\ \Delta R_t^I &= (R_t^I - R_t^{I'}) = (0.05)(0.15)R_t^C\end{aligned}$$

These same estimates of lost revenue will also serve as the basis for our estimate of lost producer surplus for carriers, handset manufacturers and third party content providers. An additional source of lost revenue for firms is the lower level of carrier investment in 3G infrastructure. To estimate these revenues, we estimate that carrier spending on 3G network infrastructure will decline by 5% while the Order is in place or before a work-around is developed. We estimate 3G network infrastructure spending to be approximately 15% of carrier revenue.¹⁶

D. CONSUMER SURPLUS

As described above, consumer surplus is the value consumers place on a purchase above what they have to pay for it. This measure of surplus can be estimated by taking an individual's willingness to pay for a product, and deducting its cost (at market prices). Market prices can be observed or estimated, but consumers' willingness to pay must be estimated from market demand curves.

Market demand curves inform us as to how much consumers adjust their purchases in response to a price change. This sensitivity is captured in the "price elasticity of demand," which we will

¹⁴ CIBC, 2007 Handset Forecast Update, November 27, 2006

¹⁵ Exhibits 6 and 7 of CIBC "US Wireless On Track to Deliver Solid Financial results" September 26, 2006.

¹⁶ Using CTIA data from 1985-2004, we regressed annual industry investment on annual industry service revenues, estimated that capital expenditures are approximately 25% of revenues. Knowing that much of network infrastructure investment to launch 3G services has been complete, we reduce this amount to 15%.

simply denote by “ e .”¹⁷ The more price sensitive are consumers (*i.e.*, the larger is e), the smaller is their willingness to pay because they apparently readily turn to substitutes when prices increase.

We make the conventional assumption that the market demand displays *constant* elasticity throughout the range of possible prices.¹⁸ This is a very popular specification used to estimate demand for many consumer products, including telecommunications products and services. In this case, we can formally express the change in surplus that consumers derive from the option to be able to purchase a product such as 3G services:

$$\Delta CS = \frac{\Delta(p \times q)}{e - 1}$$

The numerator is simply the change in the sales of the product given by multiplying the market price by the change in the total quantity sold.¹⁹ This formula is used to measure surplus lost to consumers who are unable to purchase 3G mobile subscriptions, handsets and content as a consequence of the Order.

To implement the formula, we combine the estimates of lost revenues described above with elasticity estimates found in the published economics literature. In fact, we did not find any studies that specifically estimated consumer demand for 3G mobile wireless services and handsets using historical U.S. data, which is unsurprising given that 3G services only recently appeared in the marketplace. Instead, we use elasticity estimates from related markets to serve as proxies for the elasticity measures we need for 3G mobile subscriptions, handsets and content.

We base our elasticity estimates on experience in related markets that reflect the type of consumer choices relevant to the decision to purchase 3G equipment and services. The values we used are described below:

- (1) Subscription to 3G: A principal difference between 2G (and 2.5G) mobile service and 3G service is the transmission speed. Therefore we want to measure the elasticity of demand for the incremental data speed of going from a slower service to a 3G service, not the total elasticity of demand associated with the choice between mobile service and no service at all. No empirical studies measure this elasticity directly. Instead, we look to a related market: broadband Internet service. We believe that, conceptually, the choice to upgrade from dial-up service to broadband service is comparable to the choice to

¹⁷ In words, price elasticity of demand is defined as (negative of) the percentage change in quantity of a good purchased when the market price of that good goes up by 1 percent. In that case, e is a positive number.

¹⁸ To be precise, the market demand curve would then take the form: $D(p) = p^{-e}$ where p is the price of the good and e is the constant value for price elasticity.

¹⁹ The consumer surplus is not given by this expression when $0 < e < 1$. When demand is “inelastic” it must be modified by recognizing consumers have a maximum price they will pay. Otherwise, the demand curve would imply that households would spend more than their income on a single good. The elasticity estimates we use are not in the inelastic range so we need not introduce this complication.

upgrade from 2G to 3G mobile wireless service. We surveyed estimates of price elasticities found for the adoption of broadband service by households that decide whether to upgrade from dialup narrowband service. Those estimates range from about 1.5 to about 3.0²⁰, so we choose a value of 2.2 for price elasticity of 3G service for our calculation.

- (2) Purchase of Handsets: Similar to the 3G subscription elasticities, we found no direct estimates of the elasticity of demand for handsets, and so we again turn to an analogous market: personal computers. We use estimates of demand elasticities for personal computer purchases in place of elasticities of 3G handsets. Historically, the cost of PCs has exceeded that for handsets, but now the range of prices is beginning to overlap. We draw on the many empirical studies of consumer demand for personal computers for price elasticities of 3G handsets. With the range of elasticities of aggregate U.S. demand for personal computers from 1.4 to 3.0, we settle on a value near to 2.0.²¹
- (3) Subscription to Mobile Content and Applications: We look to consumer demand for content and applications that are used on home video game and other platforms for elasticities, and select a value of 2.5.

As a practical matter, we add up the lost consumer surplus across all prohibited purchases over the effective period of the ITC Order. Those period-by-period measures of consumer surplus are then discounted back to the present using the risk-free interest rate approximated by one-year Treasury Bills adjusted for inflation. This *social discount rate* is commonly used for summarizing the present value of consumer surplus losses that occur over time.

E. PRODUCER SURPLUS (LOST PROFITS)

Producers affected by the ITC Order consist of any firm in the four-tier mobile wireless supply chain which includes retail service providers (carriers), handset (and peripheral equipment) makers, suppliers of content and applications, and network equipment vendors. We do not take any account of the suppliers of mobile wireless chips and chipsets. To find profits lost as a result of the ITC Order, we first estimate the impact of the ITC Order on firms' (gross) revenues and then apply the relevant profit margin to those revenues to get lost profits.

The presumption of this exercise is that one minus the profit margin accurately measures the avoidable cost incurred in generating those revenues. Where possible we make adjustments to the profit margin to reflect the extent to which costs of supply are sunk at the time that the ITC Order takes effect. At one extreme, all the capital expenditures made to generate a revenue stream are sunk at the time of the ITC Order, in which case most of the subsequent sales

²⁰ See, for example, Austan Goolsbee, "Subsidies, the Value of Broadband and the Importance of Fixed Costs" (December 5, 2001), which states that "These estimates [of broadband price elasticities] have indicated a fairly elastic demand for broadband, ranging from -1.5 to -3.0...."

²¹ See, for example, Jerome Foncel and Marc Ivaldi, "Operating System Prices in the Home PC Market," *Journal of Industrial Economics*, June 2005; 53(2): 265-97.

revenues would be counted as lost profits. To estimate profit margins, we begin with industry gross profit margins in the first quarter after the ITC Order takes effect, and then lower them at a linear rate down to operating margins over a two-year period. The data are taken from annual reports and SEC filings for representative firms in the various industries. The margins for the four industry groups are given in the Table 1 below.

Table 1: Industry Profit Margins

	Wireless Carriers	Handset Manufacturers	Third-Party Content Providers	3G Network Infrastructure
Gross Profit Margin	35%	30%	60%	35%
Operating Profit Margin	8%	15%	10%	15%

As with consumer surplus, we add up the lost producer surplus across all affected industries over the effective period of the Order. The quarterly lost profits are then discounted back to the present using the industry weighted average cost of capital.²² The discounting reflects the risk premium shareholders require to invest in the affected industries. We apply the industry-average cost of capital for “telecommunications services” of 10.54% to mobile services and mobile content, and the cost of capital of 16.01% for “telecommunications equipment” for handsets and network equipment.

Missing from this calculation are the follow-on disincentives caused by the appropriation of the sunk investments. To the extent that future projects involving significant sunk investments are not undertaken because investors infer a positive probability of appropriation by government policy, the incremental consumer and producer surplus from those projects should be added to lost total surplus.

F. LINGERING EFFECTS

When the ITC Order is no longer effective—either because the ‘983 patent has expired or because non-infringing handset solutions to the excluded products are widely available in the marketplace—the markets will not instantly jump to the levels they would have reached with no Exclusion Order. On the contrary, we believe there will be “lingering effects” from the Order after it becomes ineffective, and that they will contribute to cumulative lost consumer surplus and lost producer profits.

When the Order is no longer effective, consumers will be using handsets that they otherwise would have replaced. Many of these consumers will have entered into new multi-year contracts,

²² We applied an updated 1-year T-bill rate of 4.98% to the WACC calculation from http://pages.stern.nyu.edu/~adamodar/New_Home_Page/.

and early termination penalties will make them reluctant to switch once excluded products become available. In the meantime, they will have acquired less experience using the 3G-specific features, content and applications. Service providers and handset makers will have put on hold many of their development projects related to excluded handsets and compatible services during the exclusion. The same applies as well to content and applications suppliers and network equipment vendors who likely have also shifted their development efforts away from the excluded products toward the WCDMA platform. For example, many game developers will likely abandon the BREW platform under the downstream product exclusion and turn instead to the Java J2ME platform.

We assume a 12-month recovery period before the industry rejoins its baseline forecast. During this period, the gap between the two forecasts is assumed to shrink by 25% of the original gap each quarter, so that after one year the industry will resume levels that would have occurred in the absence of the Order.

G. SPREADSHEET IMPLEMENTATION

The various parameters and time series data, and the formulas that relate them to one another, are incorporated in an Excel spreadsheet. The spreadsheet has fields in which the user can enter values for several parameters that are used to make the calculation. Several other parameters are hard coded into the spreadsheet, but could be changed by simple editing of cell formulas. When the calculation is run, the program generates the present value for lost surplus for all consumers combined, and lost profits for all firms combined, assuming one, two and three years pass before a non-infringing handset solution appears.

Among the parameters governing the calculation are the span of time before patent expiry when a work around is available, the length of lingering effects, profit margins in various industry sectors, the number of 3G handset sale lost in 2007, and the elasticity of demand for 3G handsets. A list of some of the more important parameters, along with their default values, is shown in Table 2 below.

Table 2: Sample Model Inputs

Parameter	Default Value	Source
Lost 3G Handset Sales in 2007	10 million – 20 million	Gartner, Bernstein Research analyst reports
Quarterly increase in Carrier ARPU (2G to 3G)	\$15	CIBC, HSBC research reports
End of 2011 3G subscribers with no Order	216,964,000	Yankee Group research report
Average Price of Handset in 2Q2007	\$143	CIBC research report
Differential between 2G and 3G Handsets	\$45	HSBC Research report

