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Computerization and Skills: Examples from a Car Dealership

Frank Levy
Department of Urban Studies and Planning, MIT

Anne Beamish
Department of Urban Studies and Planning, MIT

Richard J. Murnane
Graduate School of Education, Harvard University[1]

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[1] The authors can be contacted at flevy@mit.edu, anneb@mit.edu , richard_murnane@gse.harvard.edu and dautor@mit.edu. . They wish to thank the Alfred P. Sloan foundation, the Russell Sage Foundation and the MIT-Ford Research Collaboration for financial support. Thanks also go to Larry Conley, Manager of the Ford Star Network, Nancy Jarosz of the FordStar Network, Randy Davis of MIT's Artificial Intelligence Laboratory, Pete Szolovits of MIT's Laboratory for Computer Science, Sendhil Mullainathan of MIT's Economics Department, Mary Curran of Discovery Brokerage, Doug Salmon and Dave Berry (now retired) from the Ford Motor Company's New England Region, and managers, technicians, service representatives, salespersons and parts staff of the "Sam Adams Motors" automobile group without whom this paper could not have been written.

III. Computers in an Automobile Repair Facility

On any day, Sam Adams Motors has approximately 18 technicians working in its service department. Some are "A" technicians (the designation is informal) competent to diagnose the most difficult “driveability” problems – for example, tracking down the reason for a “check engine” warning light. Depending on daily demand, “A” technicians may also work on a variety of simpler problems.

Some are "B" technicians who are knowledgeable in particular areas: overhauling transmissions, rebuilding an engine and so on. “B” technicians also work outside their primary area but may require help doing so. The remainder are “C” and “D” technicians who handle the most routine work: brake replacement, tune-ups, oil changes.

In this facility, a technician's grade determines the form of pay as well as the pay rate. Two of the “A” technicians are paid by clock time. All other technicians (including, by choice, the third “A” technician) are paid on a "flat rate" basis. The flat rate system is based on Chilton's *Auto Repair Manuals* that assigns, for each model and year, the amount of time a competent technician should require for the completion of standard repair tasks (e.g. replacing the clutch and/or pulley on the air conditioner compressor motor in a 1997 Ford Taurus with a 3.8 litre engine). The technician bills each task performed at the Chilton time estimate and he is paid according to his hourly rate. A payment structure of this kind rewards speed[2] and an experienced technician can bill 48-55 flat rate hours in a 40 hour week. Flat rate wages run from $8-$10

[2] Conversely, the flat rate system in isolation does not reward fixing the car properly. The service manager creates external pressures to get jobs done correctly because the shop typically takes a loss when a repair is redone. In the case of a cash job, it is hard to ask a customer to pay twice. In a warranty job, Ford will not reimburse twice unless the shop can demonstrate that Ford was at fault (e.g. a faulty part). Several years ago, Ford encouraged dealers to pay all technicians by clock time rather than flat rate time. The system was abandoned in most dealerships when Ford concluded that productivity had suffered, with no corresponding increase in repair quality. The shop is willing

dollars an hour for a "D" technician (e.g. oil changes) up to $16-$20 dollars per hour for a "B" technician, depending on the technician's experience, the fields in which they are certified, etc. Flat rate incentives and certifications both play roles in the evolution of electronics in Ford cars and we discuss these roles in Section V.

In daily work, a technician encounters computers[3] in four main areas.

- The Car[4] Cars have always contained electronics – the magneto used to fire spark plugs in the original internal combustion engines. Within Ford cars, the current generation of microprocessor controls began in 1978 with the EEC1 (Engine Electronic Control, version 1, or "eek-1") installed in the V8 engine of the Lincoln Versailles. EEC1 was an electronically controlled fuel injection system that replaced the mechanical carburetor. The unit controlled the fuel-air mix using a rules-based IF-THEN logic, reading the state of the engine through sensors measuring fuel flow, engine temperatures, oxygen concentration and so on.

  Over time EEC1 was extended to all V8 engines (which meant all Lincolns and Mercuries, cars that only came with V8 engines) and some Fords. By the mid-1980s, EEC1 had evolved into EEC2 and was extended to 6 cylinder engines as well which meant they were now in all Fords. By the late 1980s, electronic controls were extended to the car's transmission, coordinating the transmission's gear with other aspects of the engine control. Still later, electronic controls appeared in circuits governing airbags,

to pay "A" technicians per clock hour, rather than flat rate hour, because they frequently work on non-routine problems for which there is no Chilton estimate.

[3] Recall from Section I that we are using "computers" in a broad sense to include personal computers but also, control devices that use microprocessors, satellite transmission networks, etc.

[4] We are indebted to Dave Berry, a recently retired faculty member at Ford's regional training center in Southborough, Massachuesetts, for this history.

increasingly complex sound systems, electric seats that could remember preferred positions, anti-theft alarms and so on.

A priori, skill-biased technical change can proceed through either or both of two mechanisms. One is the elimination of problem solving with low skill requirements- the check clearing described earlier. The other is through raising the training and/or skill requirements of new jobs or jobs that continue to exist. The history just described potentially falls into the second category. The development of microprocessors made it possible to redesign aspects of cars in order to pursue several complementary goals: to meet fuel economy and emission regulations; to create attractive features that differentiated Ford cars from competitors' cars; to make the car more complex in ways that give factory authorized dealers an advantage in repairing it, and so on.[5] Since technicians must service the cars, these changes can drive skill-biased technical change to the extent that servicing the redesigned car requires a technician to have a more training and skills. We address this question over the course of the paper

- Diagnostic Tools With respect to the difficulty of repair, the new electronics have two characteristics that work in opposite directions. Electronics make repair harder because they are largely opaque. With few exceptions – a broken wire in a circuit, a lose connector – a failed electronic component offers none of the visual cues of, say, a leaking gasket. At the same time, electronics may make repair easier because they are based on "IF-Then" logic and so can often be diagnosed using "IF-THEN" logic embedded in computerized diagnostic tools.

  By the spring of 1999, most electronic components in Ford cars had self-tests that are run through one of two diagnostic computer tools. The Service Bay Diagnostic System

(SBDS) was a computerized diagnostic system mounted on a large, wheeled cart. The cart was rolled to the car in the service bay and was attached to parked car. Different tests were conducted with the engine running or off. Information in the SBDS was updated through CD-ROMS and covered tests for models dating back to 1992.

SBDS is also used to recalibrate the settings in the engine's electronic controls (currently EEC4). Ford develops recalibrations frequently to improve performance of existing engine models. The recalibration codes are broadcast by satellite and downloaded into the SBDS at night when it is normally not in use. Once in the SBDS, the codes can be used to reprogram a car's engine controls.[6]

The second computerized diagnostic tool is the New Generation STAR tester (Self-Test Auto Response), a hand held T-shape computer that attaches to car's data link connector under the dashboard and to the car's cigarette lighter socket from which it draws its power. This unit is designed to test components when the car is parked (with the engine on or off) or when the car is moving. The fact that the tester makes use of a single data link connector makes it significantly more convenient than earlier testers which had to connect to different components separately.

In addition to self-tests, Ford cars now contain flash memory chips to record some failures as they happen on the road. The stored information is useful in diagnosing intermittent problems – periodic failures that cannot necessarily be generated by the technician in the shop. The SBDS and New STAR tester can access this stored information as well.

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[5] The addition of features corresponds to the economics literature on competition through quality ladders. see Grossman and Helpman, 1991. A manufacturer might also add features to make a product harder to reverse engineer and clone.

A final diagnostic tool is a "breakout box" which connects to a main electrical junction box in the engine compartment and tests the integrity of many electrical circuits in the car. These tests are performed when the car is parked and the hood is up.

The result of these developments is a race between more complex on-board electronics and better diagnostics. Many people assume that diagnostics win the race, deskilling the work in the sense that repairs can now be made by persons following rules-based diagnostics even though they lack much knowledge of the underlying system. Orr (1996) writing about Xerox repair technicians, summarizes a similar view (to which he does not subscribe):

> Directive documentation belongs to the scientific management tradition of attempting to rationalize the work process (Braverman 1974). The basic premise of scientific management is that one can reduce the best way to do a given job to a set of instructions and give those instructions to someone who does not know how to do it independently but who will then be able to do the job by following instructions. In this way, management gets control over their employees, through control of the knowledge necessary to do the job, and can hire cheaper employees, since they do not need skilled labor. (p. 107)

While the Xerox technicians studied by Orr did not have computerized diagnostic tools, one can imagine that these the tools only reinforce the picture: the unskilled employee uses computerized tools that embed-rules based reasoning to find the broken component and replace it with a good one.

There is, of course, some truth here. The purpose of diagnostics is to move a problem from being a unique situation to being a routine situation - from a problem requiring model-based reasoning (an understanding of the whole system) to a problem requiring rule-based reasoning. But for two reasons, our observations warn against taking this view too far.

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[6] By the end of this year, the SBDS will be phased out and replaced by replaced by a lap-top unit, the WDS (World Diagnostic System) 1.

First, diagnostics can't anticipate all of a modern car's problems. In a static domain where large numbers of contingencies are known (chess), someone willing to spend enough money can write a set of rules that can often be successful (IBM's Deep Blue). But as we have seen, cars continue to evolve and the growing number of electronic components can create unintended interactions that are very difficult to diagnose. Binkin (1988) and Orr, among others, discuss the limitations of pre-packaged diagnostics in other contexts.

Second, a technician can't really apply rules-based reasoning to electronic situations without some understanding of electronics. The situation is similar to a that of the sixth-grade student who does not understand square roots but is taught how to compute them on a calculator. If the student makes a keying error and the calculator reports that the square root of 1,500 is 750, the student has no sense that the answer is crazy.

To summarize, in a world without diagnostics, the introduction of microprocessor electronics would require a technician to know electronics well enough to apply model based reasoning. The presence of diagnostics lowers this requirement to a point - rules-based reasoning will often do - but the technician still must have some understanding of electronics, something technicians did not need 20 years ago.

- <u>Data Bases</u> While diagnostics are not perfect, they are very useful in many situations but only if they are accessible to the technician. Ford makes diagnostics accessible through two related data bases.

  The Service Bay Technical System (SBTS) is, in essence, a frequently updated digitized shop manual which is heavily indexed by search engines. The system is contained in a networked personal computer that receives information both from CD-ROMS and from direct connections to computers at Ford. The CD-ROMS are the equivalent of manuals for each car that are updated monthly. The technician accesses the information by inserting in the appropriate CD-ROM and using a computerized index/search engine The same terminal can also connect to OASIS (Online Automotive Service Information System) an online compilation of service bulletins that describes recently discovered problems and their solutions that are not yet incorporated into the manual. The technician accesses OASIS by entering the year and model of the car, the vehicle identification number (which identifies the period during which the car was assembled[7]) and a trouble code that identifies the general problem area (e.g. brakes, transmission, driveability and so on. OASIS then produces the list of service bulletins that are relevant to the trouble code for the model in question.

- Satellite and CD-ROM based Training. A technician advances by obtaining certification in particular problem areas - brakes, electrical system, etc. The most advanced courses are given in classrooms at a regional training center. More basic courses are delivered through CD-ROMs and over the FordStar satellite network. FordStar courses utilize a two-way link between the Dearborn, Michigan studio and the dealership. The satellite transmits the live lecturer to a television set in the dealership and a 1-800 phone connection allows the technician to key in answers to multiple choice questions and to ask questions of the instructor (with a transmission delay).

For purposes of this paper, the question is whether these developments have changed the skills required of technicians. We have begun to argue that they have. We refine that argument in the next section by describing four cases.

[7] Even within a model year, a design or assembly problem is sometimes corrected so that, say, a cars made in March no longer have a problem that existed in cars made in the previous October.

IV. Four Car Problems

Case 1: Weak Acceleration

A customer brought in a 1996 Ford Probe saying the car had little power during acceleration. He said he thought the problem must be that the transmission was slipping. The dispatcher assigned the job to Bobby (all names are changed) one of Sam Adam's three "A" technicians. The assignment was made because Bobby was free - this was not an "A" problem in difficulty. In diagnosing the problem, Bobby's first step was to attempt to replicate the problem. Like all technicians, Bobby regarded the customer's problem description as important information but he did not take the customer's diagnosis (slipping transmission) very seriously since few customers know enough to distinguish among causes.

As Bobby drove the car, he determined that the engine did lack power in acceleration. Based on the feel of the car, Bobby recognized that the problem was not in the transmission but in an engine that was "missing" - i.e. the sparkplugs were misfiring and so the engine was not producing full power.

A priori, misfiring sparkplugs can be caused by a variety of faults in the ignition system. Again based on his experience, Bobby said, “When the engine is missing the first place you look is the plugs and the wires.”

Bobby began to disconnect the spark plug wires (leads) from the spark plugs in order to check them more carefully. The spark plugs sit in wells molded into the valve covers, metal shells that sit on top of an engine. In the first spark plug he checked, Bobby saw that the spark plug's well contained collected oil. The oil had rotted out the rubber shield that covers the end of the spark plug wire where it connects to the spark plug. Upon seeing this, Bobby knew there almost certainly was a leak in the valve cover gasket, the gasket that sits between the valve cover and the cylinder head.[8] The damaged gasket was causing oil to leak out and to collect in some of the spark plug wells, occasionally shorting out the plugs and causing the misfiring.

This is a traditional problem, the kind a technician might have repaired in 1950. Bobby's solution involved a variant of model-based reasoning. From his experience, he had a good mental model of how the Probe engine worked, how it should behave during acceleration, and so on. Because he had seen this problem so often, he had reduced his experience to a rule: “When the engine is missing the first place you look is the plugs and the wires.”[9] But this was not equivalent to using a rule from a manual divorced from other knowledge. If the plugs and wires had been ok, Bobby would have utilized his mental model to generate other possible areas that might have caused the problem. Working from his mental model, he would have examined these areas comparing how they looked compared to how they *should* have looked.

It is also worth noting that all of Bobby’s data came from sensory inputs - the feel of the car, the sight and touch used to determine the oil leak around the base of the spark plugs. And because this was an old problem, its diagnosis did not require acquiring new information through, for example, reading a set of diagnostic tests in a manual.[10] To the contrary, the long history of leaking valve covers combined with the problem's physical nature suggests that Bobby could have learned how to diagnose it without any reading by watching somebody else fix it

[8] The valve cover head bolts to the cylinder head, the metal casting that forms the top of the cylinders where the gasoline-air mixture is ignited. The valves - metal stems that flare into round bases - move up and down in the cylinder, opening and closing holes that let gasoline/air mixture enter the cylinder and let exhaust exit. The tops of these valves move in a bath of oil above the cylinder head. The valve cover keeps this oil from dissipating over the engine compartment.

[9] Rasmussen calls this kind of strategy “skill based reasoning” in which model-based experience has been reduced to automatic responses that no longer require a conscious consideration of the underlying model. See, for example, Rasmussen et. al., 1994, chapter 4.

[10] Fixing the problem (as opposed to diagnosing it) did require a little reading. The Ford Probe, and many other front wheel drive cars, pack components very tightly into the engine compartment and Bobby used a diagram to check the order by which other parts had to be removed before he could remove the valve covers.

Case 2: The Alarm that Wouldn't Arm

A customer brought in a newly purchased Ford Explorer sport utility vehicle. The Explorer had an Eddie Bauer (luxury trim) package that included a factory installed anti-theft alarm. The customer, however, found the anti-theft alarm would not "arm": even after the windows were closed, the car was vacated and the doors were all locked, the alarm could not be set to the on position. Once the problem was discovered, a technician determined that two other Eddie Bauer Explorers, not yet sold, had a similar problem.

Because this was a potentially complex electrical problem, the car alarm had to be assigned to an "A" technician, again Bobby as it turned out. But Bobby's approach the alarm differed substantially from his approach to the weak acceleration (Case 1). Because the alarm problem was electrical, many potential causes could not be assessed by sight or touch or hearing - they had to be assessed through the use of computerized diagnostic equipment. And because the problem was rare, Bobby had no mental model of how the system was organized. He had to consult the Ford Explorer manual to determine the appropriate sequence of tests and to obtain the alarm's wiring diagrams. He also searched OASIS for any recent service bulletins that would not have been listed in the manual but none were listed.

Because the procedures covered a number of pages, Bobby used the hard copy manual. He could have printed the same information from a CD-ROM, using the Service Bay Technical System. Since the problem was clearly situated in the anti-theft alarm, locating the diagnostic instructions in either paper manual or on the CD-ROM was straightforward.

The printed pages began with a brief summary of the structure of alarm circuits and operation. They next presented a series of initial tests to be conducted with the New Generation STAR tester (see above) to check for the general condition of the system. The manual then directed Bobby to Pinpoint Test B, the test that was to be performed when the alarm system does not arm/disarm. Pinpoint Test B continues for a total of 15 pages. It involved testing every part in the alarm: the sensors on the doors, the alarm module itself, the integrity of the circuits connecting the components and so on.

Bobby ran through the entire sequence of tests and discovered nothing. According to results of the rules-based computerized diagnostics, all components and circuits were working properly and so the alarm should have been working which, of course, it wasn't. At this point, Bobby followed standard procedures by calling the Ford Technical Assistance Hotline in Dearborn, Michigan and, subsequently, the Ford factory in Cincinnati where Explorer had been made. Neither location had a solution.

Bobby then moved to model-based reasoning by beginning to examine the system's wiring diagram. Working through the diagram, he began to test components and to visually inspect those parts of the system that were exposed, comparing the wiring to the wiring patterns in the diagram. Ultimately, he found the problem behind an inspection panel in the rear of the car: a 2" piece of wire, not listed in the manual, that created a circuit between two junction blocks using receptacle holes that, according to the wiring diagram, should have been unused. The wire shorted out a circuit such that a door sensor could not determine that the car doors were locked. As a result, the alarm would not arm. Cutting the piece of wire in two broke the short circuit and fixed the problem.

This is a modern problem, one that would have not occurred in 1970. Bobby began his solution by consulting a manual. His reading of the written documentation produced a set of rules based diagnostics using the New STAR tester. In applying these diagnostics, Bobby had no sensory inputs but rather had to proceed based on digital readouts from the tester. When the rule-based diagnostics failed to provide an answer, Bobby switched to model-based reasoning, working with a representation of the system (the wiring diagrams) and his knowledge of electronics to see if he could locate a fault.

Bobby is an "A" technician - not all technicians understand electronics as well. But as noted in the previous section, even "B" and some "C" technicians have to have some feel for electronics to follow diagnostics intelligently. In addition, these technicians must know how to read well. According to one senior trainer at the regional Ford Training Center (now retired), neither electronics nor reading were skills that came easily to all technicians.

Through the mid-1970s, few technicians had any incentive to learn electronics. Then as now, most technicians worked on a flat rate system (see Section III). At that time, however, Chilton did not estimate flat rate hours for electrical repairs and so technicians were paid for electrical repairs based on actual clock time. This meant that the technician's way of increasing income – doing a job in less time than the Chilton estimate – could not be done on electrical work, and so technicians saw little reason to learn about electronics.

In the late 1970s, the introduction of EEC1 on V8 engines made it imperative for at least some of a shop's technicians to be proficient in electronics. Ford initially took a passive role, providing training but not requiring it. It soon emerged that a lack of training was generating heavy warranty expenses as undertrained technicians tried to fix a problem by "throwing parts at it" - by replacing components, whether or not a technician knew the components were at fault - in the hope that something would work. In response, Ford required that only certified (trained) technicians could make warranty repairs involving the replacement of two or more components. Warranty repairs made by non-certified technicians would not be reimbursed.

During the late 1970s and early 1980, the senior trainer estimates that perhaps half of the technicians taking electronics courses could not pass them. For some, the problems began with reading - they had learned how to repair cars through experience and by observing others but they could not learn large amounts of material from written text. For many, the problem was that basic electronics involved a different logic than mechanics. The relationship among components was different and there was often nothing to see: the flow of the current through the wires, the role of the ground in a circuit, and so on.

An example illustrates the problem. By the late 1980s, the trainer was conducting three-day courses for transmission specialists on the newly developed electronic transmission controls. Toward the end of the first day of one course, one technician threw up his hands and began to leave. The trainer asked him how he expected to diagnose transmission problems if he didn't learn the material. The technician replied that in his shop, they divided the labor: "The EEC man [the specialist in electronic engine controls] and I diagnose the problem. If it's an electronic problem, he does it. If it's a hard part [mechanical] problem, I do it."

To be sure, many of these technicians were already middle aged and so may have had difficulty learning new material. One dealer has told us that his technicians now appear to peak at ages 35-40; after that, they have difficulty keeping up with the flow of new material.[11] Today's young technicians may have an easier time learning electronics than these stories suggest. It is clear, however, that electronics constitutes a distinct domain of knowledge, different from mechanical knowledge. As the volume of electronic components in cars has increased, service managers tell us that any technician now hired for an "A" or "B" job must have a feel for both electronics and mechanics.

[11] Given the basis for technician pay, this effect should be testable given the appropriate income data. We are looking.

All this suggests that computerization has raised skill requirements for "A" and "B" technicians in two ways: by requiring them to read at higher levels (because their reliance on manuals has increased) and by requiring them to learn two domains of knowledge rather than one.

To complete the story, the 2" jumper wire there in the first place through a misunderstanding between the factory and dealer: the factory had incorrectly assumed the customer did not want the alarm to work. The real problem, then, was not in the car but in a miscommunication in the ordering system. For our purposes, however, the important fact was that the situation forced Bobby to do extensive reading, to be able to interpret digital read outs, and ultimately to have a basic feel for electronics, none of which were required for the acceleration problem.

Case 3: The Stumbling Engine

A long time customer brought in 1996 Ford Taurus with the complaint that the engine would stumble during acceleration. Unlike the earlier case of the Ford Probe where the engine appeared to constantly run weak, the Taurus engine would run at full power and then suddenly begin to die before recovering again. This was, the customer reported, an intermittent problem.

Lou, the "B" technician assigned, knew the customer and trusted the customer's description of the symptom. He could not, however, verify the problem in a test drive. The 1996 Taurus electrical system can store some trouble codes as a problem occurs, to be read later in the shop by the STAR tester. There were no stored trouble codes in this case.

Lou used the New Generation STAR tester to test the ignition and fuel system following a sequence of diagnostic steps, similar in spirit to Table 1, which he printed off the Service Bay Technical System. While he generally knew how engines operated, here he was following rule-based reasoning to examine the calibration of the car's electronic fuel-air system. In these tests, two sensors tested slightly outside their normal range, a fact that merited an adjustment, but Lou, now reasoning from experience, did not believe the deviations were large enough to be the cause of the stumbling engine.

After Lou had completed the tests and found no obvious cause, he queried the OASIS data base to look for any recent service bulletins that might fit the problem. OASIS produced a list of several recent service bulletins including one that closely resembled the problem at hand. The solution involved replacing the Manifold Absolute Pressure Sensor, a repair that would cost the customer about $200. Lou recommended the repair to the customer, telling her that since he could not replicate the problem, he could not guarantee the new sensor would fix the problem but he was reasonably sure it would work. The customer, who had dealt with Lou before, trusted him and authorized the repair.

The point of interest in this case is not required skills - the skills involved reading and following rule-based logic - but rather the role of computerization in disseminating diagnostics - i.e. of moving problems from unique to routine.

The OASIS system informed Lou of a problem that had not been recognized when the 1996 Taurus shop manual had been written. The process of "informing" Lou involved two complementary actions: moving the information to from Ford headquarters to Sam Adams Motors (by satellite), and organizing the information in a form that made it easily accessible to Lou, in this case by search engine. This second action is worth some attention. If the only issue were moving information rapidly to the dealership, that could be done by mailing paper copies of service bulletins by overnight mail. The next step would be to insert the service bulletin into the appropriate shop manual. But since the typical shop manual is three inches thick, the service bulletins would not be easily accessible unless the shop manual index was revised as well. When service bulletins are added to a digitized file, indexing is automatically accomplished as long as service bulletins are assigned the proper trouble codes (i.e. keywords).

The gains from this digitization become apparent when the service bulletin addresses a problem that is both widespread and difficult to diagnose. Several years ago, the Ford Taurus began to present a variety of different problems: the electric seats, air conditioning and/or sound system would stop working on an intermittent basis. It emerged that these various problems would occur when the automatic transmission was in first gear or reverse. Ultimately, the problem was traced to a fault in the range sensor, a transmission sensor that coordinated the gear of the automatic transmission with the fuel/air mixture entering the engine. When the automatic transmission was in first gear or reverse, the sensor could short out a ground circuit that, in turn, would cause the failure of the sound system, power seats, etc.

Ex post, the problem was easy to explain. Ex ante, it was an example of the unanticipated interaction among components noted in Section III. Based on the customer's report, a technician might believe he was looking at an air conditioning problem or a window problem or an electric seat problem or a sound system problem. Computerization saved substantial time by being able to rapidly disseminate the problem and to cross- reference it appropriately so that, for example, a technician searching for electric seat problems would encounter it. Using the analogy in Section II, not only was the cook able to describe the dish in a recipe but she was able to get the recipe into the hands of many other cooks.

A corollary of this process is that computerization has also substantially increased the value of a technician who can first diagnose and solve a new problem - someone "who can write good rules" – because the rules can be quickly disseminated to others.[12] Whether the technician himself receives the additional value is an open question. When a technician solves a new problem, Ford encourages him to electronically mail it to the company for review. Ford's rewards for a successful fix are modest, however. And, of course, no single dealer will heavily reward a technician for a solution that benefits all Ford dealers.[13]

Case 4: Marrying the Customer

To emphasize the importance of information dissemination, we conclude this section by briefly describing what happens when important information is not available.

In some cases, and despite the technician's best efforts, a car cannot be fixed or at least fixed quickly. The customer is left immobile or worried about safety and so keeps returning to the dealership to fix the problem. This is called "marrying the customer" and it is something to be avoided since it generates both financial and reputational costs.

In practice, marrying the customer is more likely to happen on an old car. Existing data bases are poorer (the Service Bay Technical System does not cover model years before 1992), parts are harder to come by, informal knowledge from other mechanics and Ford engineers has receded into memory. Even when a problem is fixed, an old car is more likely to develop a new problem that the customer believes should have been covered in the last trip to the shop. Many service

[12] Models of endogenous growth (e.g. Romer, 1986) emphasize the non-rival nature of ideas in production. In practice, this property of ideas offers little benefit unless an idea can be disseminated easily. That is the case here and the result is something like a superstar effect in which a good performer's value increases because technology allows the performance to reach a larger market.

[13] This is one aspect of a general incentive problem facing all organizations that wants to disseminate "front line" knowledge through the organization. Here, Ford dealers are independent entities and so a technician's discovery potentially creates unpaid externalities for other dealers. But even in unitary organizations, incentive problems arise because, for example, a service person's fix may reflect a production unit's error, something the production unit will not be thrilled to confess. John Seely Brown of Xerox PARC has explained to us that Xerox uses non-monetary rewards by attaching the technician's name to a disseminated fix. The resulting status has proven to be an effective reward in that case.

facilities will avoid this problem by inspecting the car and giving the customer a very high repair estimate so that the customer will go elsewhere. At times, however, that strategy is not an option.

Last fall, Sam Adams Motors had accepted a 1991 Lincoln Mark VII in trade. They had planned to sell the car at auction – a standard procedure for older cars – when a woman approached the used car manager and said she wanted to buy the car for her 18-year-old son. As noted above, Sam Adams does not want to sell cars this old to retail customers but the woman was known as a good customer, her son had fallen in love with the car, and so the used car manager relented.

Within a short time, the car was back in the shop for automatic transmission problems that were quickly fixed. Upon test driving the car, the technician realized the anti-lock brakes had no power assist - he narrowly missed an accident when trying to stop. These repairs were not covered by warranty but the dealer felt that had obligation to fix a problem for a reasonable price in a car it had recently sold.

Marty, the technician who worked on the car was one of the three “A” technicians in the shop. Nonetheless, he could make little progress with the problem. Because the car was a 1991 model, there was no computerized database. The original shop manual was vague on the subject. The technicians at Ford’s Technical Assistance Hotline suggested two possible solutions. After both failed to work, they had no further suggestions and said they would appreciate hearing about anything Marty found. With the help of the shop's service manager, Marty talked to an engineer who had worked on the original system. He, too, had no ideas. All this occurred over a span of more than two weeks, during which car sat quietly in a service bay with its hood open while the woman and her son grew increasingly upset. Finally, the problem was "fixed" by using electronic messaging to find an equivalent model in an automobile junk yard, removing the electronics from the car's ABS system, testing them to ensure that they worked, and installing them intact in the car in the shop.

The episode, however, was far from a success. Concern for reputation required Sam Adams to fix the car once they had sold it, but concern for reputation also precluded Sam Adams from charging the customer the full cost of Marty's time. In the end, Sam Adams suffered a financial loss and also suffered a reputational loss because the woman and son were enraged that the car had taken so long to fix. The absence of appropriate information (and a soft-hearted used-car manager) had imposed these costs on the dealership

Lube Boys and Inequality

To this point, we have focused on the "A" and "B" technicians who diagnose problems. We have argued that the computerization of the cars (and diagnostics) has raised basic skill requirements in two ways: by requiring the technicians to know electronics as well as mechanics and by requiring the technicians to read at higher levels. We also suggested that the value of very good diagnosticians may be increased (at least to the system as a whole) because information technology can rapidly disseminate solutions to other technicians.

Few of these considerations appear to affect lower level employees - e.g. the “D” technicians or "lube boys" who perform very simple maintenance like oil changes.

In these ways, it appears that computerization in car repair should have widened the gap between more and less skilled workers. We are currently attempting to collect wage information to test this idea.

V. New Car Sales[14]

[14] We have benefited substantially from conversations with Mary Curran, general counsel for Discovery Brokerage, in writing this section.

Easy rule-based tasks – tasks requiring little human skill – are not necessarily poorly paid. The fact that a task is easily learned implies that it should be in large supply and so should not command a high price. But as with any other commodity, if producers can place artificial restrictions on the supply of the task, compensation may be quite high.

A case in point is full-service stockbrokers who perform a mixture of rules-based and more complex tasks. A stockbroker's rules-based tasks - more precisely, the rules based tasks that can be programmed - include executing trades, performing simple financial planning calculations, giving out prepackaged research information and so on. The stock broker must also exercise salesmanship - convincing customers to make transactions they otherwise would not have made - and the ability to give customers comfort and confidence about the decisions they are making. Salesmanship and imparting confidence cannot be programmed. But these tasks only constitute part of the stockbroker's day.[15]

Until fairly recently, full-service brokers could charge a substantial amount for performing rules-based tasks because they had a relative monopoly on much of the required information. But as we have seen, one aspect of computerization is the capacity to disseminate information at low cost. For example, the web site of Discovery Brokerage (a unit of Morgan Stanley-Dean Witter) allows customers to place buy and sell orders, to access research on particular stocks, to use web based calculators to do basic financial planning, etc. - many of the rule-based tasks full service brokers perform.[16]

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[15] It is not quite right to say that a "soft skill" like salesmanship requires model-based reasoning, but salesmanship, like model-based reasoning, is something that cannot be broken into simple instructions.

[16] Due to SEC regulations, the employees who execute these orders must have a Series ??? brokerage license. Nonetheless, these employees earn $30-35,000 per year compared to the $125,000-$130, 000 per year earned by a good full service broker. This cost issue raises difficult issues for traditional brokerage houses who are trying to retain customers who want the web's low trading costs even as they try to retain their sales force of brokers. Merrill Lynch's recent move into web-based trading will presumably accelerate the move away from full-service brokers.

These web sites cannot “sell” - they are used by customers who already know what they want.[17] But their existence means that that the full-service brokers will be dealing with a smaller volume of customers. In the end, demand for their services will decline. Those who survive will presumably be doing more "selling" and fewer strictly rule-based tasks. The problem is compounded because brokers traditionally are not directly paid for advice, counseling, etc. Rather, all of their income is derived from commissions on stock sales and purchases. Until this pricing system is revised, brokers face the risk of being asked to provide services by customers who then turn to the web to do their transactions.[18]

Automobile sales representatives (sales reps) are in a similar position. Their jobs involve both rules-based tasks and salesmanship. Until recently, their market power rested on two market characteristics. First, a consumer who wanted to purchase a new car had to purchase it from a sales rep in a dealership. Second, sales reps had the advantage of asymmetric information in which they knew a car's true cost while the customer didn't. Computerization is now eroding both advantages.

A new car comes to a dealer with two prices: a Manufacturer's Suggested Retail Price (MRSP), and the dealer invoice. On all but the most popular models, the MRSP is a fiction, a starting point for negotiation so that the customer can get a "discount". The dealer invoice is advertised as the cost the dealer paid for the car, but it, too, contains a 3% margin - the "holdback" - to help cover the dealer's finance charge while holding the car in inventory. The dealer keeps the holdback even if the car sells quickly.

[17] The difficulty in web selling is why good web site designers are in such high demand.

[18] We thank John Reed for making this point. As Reed notes, it is as if doctors did not charge for office visits but rather were paid through commissions on prescriptions: a discount druggist would take away their income even though they were providing diagnostic and other services that a discount druggist did not provide.

A sales rep earns a commission of 25 percent of the difference between the price the customer pays and the dealer invoice. Ford vehicles typically sell at 1 to 8 percent over dealer invoice with the lower percentages being more common. Thus when a $20,000 vehicle is sold at 5 percent over invoice, the profit is $1,000 of which $250 goes to the sales rep and $750 to the dealership. The sales rep may also make an extra $50 base pay plus any incentive bonus offered by Ford for the particular vehicle. This means that a $20,000 purchase for a customer is roughly a $300 transaction for the sales rep (which is perhaps one reason why salesman may take the transaction less seriously). At Sam Adams, a good sales rep will work up to 50 hours per week, sell 10-14 vehicles a month and earn $25,000 to $80,000 a year depending completely on the number of vehicles they sell.

Computers are found on the sales floor, and sales reps use them during the sale of a vehicle, but compared to service technicians, the use is relatively infrequent. Computers are used for maintaining the in-house database of names and contact information of existing and potential customers. They are used to display vehicles in stock, and to record orders placed with the manufacturer. Some computers have software to calculate lease and retail payments, and a sales rep can connect to a Ford data base to build and price a special order vehicle. Ford now posts vehicle incentive programs on a company web site though this is more likely to be accessed by the sales manager than a sales rep. Occasionally, a sales manager will access a computer to see the models in neighboring dealers' inventories - information that may influence his own bargaining position. We can describe all of these functions by noting that many of the problems a sales rep solves depend on information and the computer is trying to improve the information the sales rep has.

The sales rep's limited use of computers does not mean the he or she is unaffected by computers. Rather, computers' biggest impact on sales reps has been indirect, giving the customer an alternative source of information and, in essence, an alternative selling channel. Both changes strengthen the customer's bargaining position. This impact can be seen in comparison of two sales:

<u>Selling a Sport Utility Vehicle (I)</u>

A couple and their two young children walked into the showroom on a weekday afternoon and move towards the six shiny new cars in the center of the room. Seven sales reps were on the floor but most were busy with clients or doing paperwork. Luke, a salesman with 10 years experience at Sam Adams, got up from his desk. Luke claims that his intuition is usually accurate, and to him these customers have the look of serious buyers.

Luke greeted the couple warmly -- the first step in the sales process -- looking each of them, including the children, in the eye while introducing himself and shaking hands with the adults. He made a comment about the threatening clouds gathering on the horizon and they discussed the likelihood of snow and the disruption of their weekend travel plans. He then asked them how he could be of help.

They said that they now have a Ford Taurus, but were looking for a second car and were interested in a sports utility vehicle. Luke was now in the second step of the sales process -- gathering information. He probed, asking about when it will be used, by whom, and for what purpose. Luke has been around for a while and he believes that taking the time to match the car to the customer's needs makes them more likely to return in the future. The couple explained that they have a cabin in New Hampshire that they like to visit on weekends so they're looking for a fairly good-sized vehicle with four-wheel drive that can hold all of them and their gear comfortably.

During the conversation, Luke found out that the couple, like him, enjoys fishing. This kind of information is important. Unlike, say, writing up an order, "selling" is not an easily taught, rule-based skill. It depends on being upbeat, having the initiative to call back people who visited the show room but did not buy, and so on. Among sales reps themselves, the most revered aspect of selling is the ability to be a "chameleon" - to adopt, with utter sincerity, a personality that emotionally connects with the customer and puts the customer at ease. The common interest in fishing might help establish that connection.

Luke listened carefully and repeats what he has heard to ensure that he understood what the couple wanted. He then said he had a couple of vehicles that he'd like to show them -- the third step in the sales process. He asked how much they are thinking of spending in monthly payments. The couple were knowledgeable buyers and said that they'd like to see the vehicles first and talk money later.

Luke showed them the Explorer and discussed possible options. He invited the two children, who were becoming visibly bored, to hop in the cars to see what they thought. The parents looked pleased at his thoughtfulness.

The couple seemed to be quite knowledgeable about the vehicle. When he mentioned this, they say that yes, they had done some background research on the Internet. This is slowly becoming the norm. A study by JD Powers and Associates (1999) suggests that 40 percent of all new-vehicle buyers now use the web to get such information before purchasing a new car. They are likely to be higher income, more educated customers - customers who previously could be counted on to buy more expensive vehicles (e.g. sport utility vehicles) with potentially higher profit margins.

Many sales reps resent the web. Luke views it as a double-edged sword. The customer has more price information - something Luke does not want - but in this case, it gives the couple the confidence to know what they want and to not be excessively suspicious and defensive.

The couple seemed very interested in the Explorer, but Luke also showed the Expedition - a larger more expensive SUV that would earn him a higher commission. The couple remarked on how much they like it, but after a quick look at the MSRP on the window sticker, they sighed and said it is way out of their price bracket. Luke jokingly said he would put one away for them - they could buy it when they were ready for their next car - and they all laughed.

Luke suggested that they go back to his desk to talk for the fourth and probably most important step -- price negotiations. On the way back, he picked up some of the promotional balloons in the showroom to give to the two children to play with while their parents talked.

The desk that Luke sat at was not actually his -- he shares it with another sales person who works a different shift, but he always puts out his name plate and a picture of his family on his desk -- another potential topic of conversation with customers. He first got their names and contact information. If, as is usual, the couple ended the first visit without buying a vehicle, Luke would be able to call them back to see how their search is going. He tried once again to find out how much the couple is willing to pay, but again, they said that they'd like to first hear an offer from him. Luke assumed that the couple have done research on the buying process (as well as on the vehicle), information that now readily available on various web sites. Correspondingly, Luke begins with a price somewhat lower than the MSRP. The couple counter with an offer 1 percent over dealer invoice. That amount would mean a commission of about

$65.00 - Luke can't settle for that - but he was relieved that the couple was discussing a price over the dealer invoice and wasn't trying to capture some of the holdback - the 3 percent margin built into the dealer invoice that some customers insist on. Luke said he can only sell them the car at their price if they're willing to give up some of the options they wanted. They discussed whether they really need the four-door, and agree that they do. Luke made a counter-offer, 6 percent over invoice. After more discussion, they decided to leave off a couple of options, and agreed on a price that is 4 percent over invoice. It was not a great price in Luke's opinion for either party, but it was certainly reasonable. The price meant that the dealership will earn a profit of $1000, of which Luke would get $250.

Luke recorded the price that they've agreed to and stands up to say that he just has to get it approved by the sales manager. The couple looked slightly surprised, but he explains that sales reps have to have all sales offers approved by the manager: the document is legally binding and the sales manager provides a check that the dealership can uphold its end of the bargain. In the case of younger sales reps, this check is also a chance for the sales manager to teach the salesman about how the deal might be improved - something, of course, the customers suspect.

Luke is experienced, the couple was not trading in a car, and the vehicle was available on the lot, all of which make the sale straightforward. The sales manager signs it and Luke was quickly back at his desk with the document in hand. The couple accepted it, but said that they'd still like to think about it and maybe look around a bit more. At this point, Luke could have put enormous pressure on the couple to sign - an approach called "buy-or-die" - but he preferred to let the customer walk out the door. This is a conscious style at Sam Adams: treat the customer well as if you expect them to return. (With a well-informed, educated couple like this, buy-or-die might not have worked in any case.) Luke was almost positive that he had a sale. He gave them his card, invited them to call him at any time, and said that he hoped to hear from them soon.

The next morning, Luke called the couple asking them if they had been able to give it any more thought or if there was anything that he can help them with. They said that they liked the vehicle. The price was slightly higher than they had wanted, but they decided they could live with it. They also said they had gone to other dealerships, but were not happy with how they were treated, so yes, they were going to buy the car, and they want to know how soon they could get it. Since the vehicle was in the lot, Luke would have it clean and prepared for them and they could pick it up mid-afternoon. Luke was pleased that the couple decided so quickly. It was not unusual for weeks to go by before customers made a final decision. This one was easy in comparison, and made up for the slightly lower price that he earned on the vehicle.

That afternoon, the couple would come in and complete the sale. In the process, Luke would have them sign the papers, offer the couple financing (which they decline), offer them an extended warranty (which they purchase), explain the warranty and the operation of the vehicle's four wheel drive, and explain the vehicle's maintenance schedule. Luke would then walked the couple to the service area and introduce them to Kathy, one of the service managers. He would have them make an appointment with Kathy to return in 90 days for a filter change. The introduction was designed to encourage the couple to return to the dealership for future repairs and maintenance, rather than go to the corner garage.

<u>Selling a Sport Utility Vehicle (II)</u>

We have described an SUV sale in some detail to show that Luke's job requires him to use significant soft skills - skills that computers cannot replicate. Customers, however, no longer have to negotiate with sales reps to buy cars. On web sites including Autobuytel, AutoVantage, AutoWeb, and CarPoint, customers choose their vehicle and any additional options they select. They fill in an electronic form with contact information and submit it to the web site. The service locates the closest participating dealer and sends them the contact information and the request. The sales person at the dealership who is responsible for web transactions, logs on to the site, picks up the request and then sends the customer a quote -- usually a standard 1%-3% over invoice. There is no negotiation. If the customer accepts the quote, they go to the dealership for a test drive, if they wish, and to sign the final papers.

As with full service stockbrokers, it appears that web-based car sales will result in restructuring the sales rep's job. In some ways, this restructuring is already apparent. As noted earlier, sales reps rely in part on the fact that they know a car's true cost while the customer doesn't. The internet and other information sources (e.g. Consumer Reports) are putting this system under pressure. To sustain margins on car sales, major car manufacturers are increasingly exploring moving toward "one-price" or "no-haggle" pricing, as Saturn does now. But with the exception of Saturn, dealership networks for most cars are too dense to sustain a fixed price[19] – the price will be undercut by dealer competition. For this reason, the move to one-price will be accompanied by a thinning out of existing dealerships, in part as manufacturers buy up dealerships. One result will be fewer sales rep jobs.

Is this restructuring consistent with skill-biased technical change? The answer is unclear and depends on the evolution of sales reps' compensation formulae. Under one-price, sales reps will no longer negotiate the price of a given vehicle. By itself, this suggests sales reps will be paid on salary and will take on the role of sales consultants, "assisting customers" rather than "selling cars". In many cases, however, this picture is too stark. Car makers still have an interest in convincing a customer to buy a bigger car or a car with more options. It is hard to imagine sales consultants performing these duties unless at least some of the compensation is tied by incentive to the value of the sale. If so, it is plausible that the contraction of sales rep jobs will cause the average "selling ability" of sales reps to rise. A similar story may apply to the case of the full-service stockbroker.

In some cases, however, one-price dealers advertise that their salesmen are paid on salary only so that their only incentive is to match the customer with the right car. Under a straight salary, it is plausible that sales reps with the highest selling skills will migrate to other industries where they can earn more money.

In this story, then, we cannot yet see an obvious implication for skill biased technical change. But it is clear that computerization will have exerted substantial influence on sales reps' employment.

(end of excerpt)

[19] Saturn is an example of this model in which no-negotiation pricing is sustained by a thin dealership network. Among other auto producers, current dealership networks are more dense and so any attempt at no-negotiation pricing would be undercut by competition.